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Chicago Meeting and Dinner

THE meeting of the Society held in Chicago on Feb. 2 was not only a marked success but was the occasion of the first national sessions devoted to the operation and maintenance of automotive apparatus from an engineering standpoint. The technical sessions held during the morning and the afternoon were well attended. Vice-President B. B. Bachman was in the chair. N. J. Ocksreider, chief transportation engineer of the Packard Motor Car Co., gave an address on Engineering Analysis Applied to Truck Selling. He said that in this day of transportation engineering the requirements of each customer must be diagnosed accurately, eliminating economic waste due to wrong selling. He stated that 32 classes of trades, divided into 350 subclasses, use motor trucks. In applying the science of selling by analysis, it is necessary to know the cost of shipping every pound of goods, deducing in turn the correct size of truck for a given kind of work. Referring to the fact that a truck cannot be designed to stand up under all conditions and that selling a truck that is unsuitable for a particular task means a dissatisfied customer, the author expressed the opinion that a truck of mediocre merit will in many cases perform more satisfactorily than the best truck made operating under improper conditions. Chairman Bachman said that the application of efficiency methods, which means the application of common-sense principles, is of inestimable benefit in truck operation. Mr. Ocksreider made a broad-minded and valuable contribution in his statement of the factors to be observed in determining the proper type and size of truck to meet a given customer's requirements in the most satisfactory manner, pointing to the many advantages derived from the making of unbiased recommendations and taking all steps possible to prevent overloading.

The Application of Steam Power to an Automotive Truck was the subject of the paper by L. L. Scott, who described the development and present status of a steam-driven 2-ton truck constructed by E. C. Newcomb and him. The advantageous features of the steam power-plant were enumerated and torque curves shown, in addition to other illustrations. The matters of engine control and fuel, oil and water consumption, were discussed and the results of various acceleration tests presented. Among other opinions voiced in the discussion of this paper was the one that engineers should not close their minds to any possible line of development that will make a greater percentage of crude oil available for automotive vehicles and that all should be open to conviction regarding new methods.

Capt. J. B. Haney, of the United States Ordnance Department, described the development of artillery automotive materiel during 1920, including the tractor hand cart, reconnaissance tractor, Division artillery tractor, Corps artillery tractor, Army artillery tractor, heavy or 15-ton artillery tractor, tractor and trailer caissons of 1½ and 3-ton capacity, and self-propelled mounts for Division, Corps and Army gun and howitzer. The hand cart, which is of the track laying type, is pushed or drawn by one or two men and is to be used for carrying ammunition or miscellaneous supplies which would otherwise have to be carried by men on foot. The reconnaissance tractor is intended to fill the gap in motorized artillery left by the horse of the individual mounted man, as it is not practicable to combine horse and motor transport in the same unit. Captain Haney stated that the use of the motorcycle, which requires fairly good rôads, is limited. The first Division tractors were built in 1918 but finished too late to be of service during the war. As now constructed, this type of tractor weighs 7700 lb. and has a normal speed range of from 3 to 9 m.p.h., although 12 m.p.h. has been maintained for short periods with it. This tractor is still in the experimental stage. The 1920 model Division artillery tractor, which was exhibited at the Society meeting last June and described in the October, 1920, issue of THE JOURNAL, has a normal range of speed from 1 to 15 m.p.h.

The Army places considerable importance on the relatively high speed, waterproofing and quiet operation of tractors, factors that have not yet entered decisively into commercial designs. The Army does not intend to build more 5 and 10-ton tractors of the types now in use but to develop a new tractor of a size between those of the Division tractor and the 15-ton tractor now under construction.

The tractor caissons built during the war here and abroad were too heavy for economical operation. Nothing has as yet however been developed to replace them.

The combined wheeled and track-laying type of tractor is considered a most interesting development, although its abilities have not been tested as rigorously as have those of the track-laying type. When operated as a wheeled vehicle it is steered by the front wheels; as there is no differential care must be taken in making short turns to release the clutch controlling the inner driving-wheel. When the track is in use, the steering-knuckles are securely locked and the vehicle steered by the clutches and transmission in the usual manner. The

tracks can be put on or taken off in a very short time by a trained crew.

In tank design the tendency is toward a smaller tank than the Mark VIII but a larger one than the 6-ton Renault.

The paper on Truck Fleet Operation, by N. J. Smith of the Consumers Co., Chicago, was very well received as showing the value of keen analysis and sound judgment in applying engineering principles in truck operation. The author argued that salesmen should have accurate information on the service policies of their companies and as to all guarantees they are authorized to make. It is felt that adequate cooperation between the engineering and the sales departments is extremely important in the psychology of truck selling. The buyer must understand exactly what he is buying, what it will do, and the conditions under which the truck will operate properly. Things that the truck builder must keep clearly in mind are the design of each individual part; the material and workmanship which go into it must be the best for the purpose, so that breakdowns shall be as infrequent as possible; and accessibility of all of the parts.

Mr. Smith said that one of the weak points in motor trucks today is ignition failure, which contributes to faulty performance through various effects. The author said, "While we await the advent of more efficient carburetion equipment, the present carbureters should be made as nearly foolproof as possible, with necessary adjustments few and simple." The use and improvement of engine governors were advocated. Mr. Smith said that the time required by two men for removing a engine from a truck varies from 1½ to 4½ hr. The company with which Mr. Smith is associated operates over 150 motor trucks in Chicago and adjacent territory, delivering coal, ice and other supplies. The loading is done in part by overhead locomotive cranes capable of handling of from 2 to 10 tons in 2 min. The time generally taken for a truck to get into the yard, secure its load and go out again is less than 5 min.

It is the policy of the company to do everything possible to prevent the trucks reaching such a condition that they require overhauling. Mr. Smith said that some of the trucks have traveled over 70,000 miles and are apparently in first-class condition. The author believes that his company is delivering coal and ice at less cost than any other firm in Chicago. Each truck is washed and inspected carefully every night. Mechanics go over the truck, tightening brake-bands, straightening mudguards and checking up on all the little things that may be wrong and might if not checked develop into serious troubles.

One surprising statement that Mr. Smith made is that it costs about as much to maintain a dump body with a hoist per year as it costs to maintain the rest of the truck. The shop equipment used by the company consists of shaping, milling and drilling machines, air and drop-hammers, special reamers for all bearings, woodworking machines and machines for painting. All of the mechanics are selected carefully and well treated.

The theme of Mr. Smith's remarks was that it is more economical to spend money in preventing trouble than to speculate against the law of averages and in the end pay as much or more for repairs.

J. C. Thorpe, an engineer who has sold trucks and tractors in Illinois for many years, gave an address on Tractor Service Requirements, treating in turn the service, commercial and technical aspects. Regarding the discussion as to whether the farm implement man or the automobile agent is the logical tractor dealer, he said the only true basis for a man being a dealer is selling good merchandise by good merchandising methods and having sold the goods maintaining them in operation through expert service. Previous experience in the work is not essential. The good dealer is entitled to his place, selling and keeping sold automotive apparatus. The success of a manufacturer depends upon keeping the good will of the trade; this must be accomplished through the dealer. The selection by a customer of the dealer rather than the equipment is evidence of weakness in manufacturing and merchandising policy.

Mr. Thorpe called attention to the fact that there can be no such thing as free service, for in the end the customer pays. He submitted the following definition of service:

> The co-operation between the dealer, the factory and the owner, during the life of the machine, whether the machine be in the hands of the original purchaser or not, to make the use of the machine feasible at reasonable cost.

He argued that the engineering departments should urge upon merchandising departments intelligent distribution through dealers, the stocking of an adequate supply of parts and the maintaining of a well qualified mechanical force for the purpose of making engineering development work in the form of farm power automotive apparatus effective. The designer and the producer should interest themselves in the merchandising policy of the factory, as this is the only procedure by which the engineers can secure to the extent merited justification for their work. Mr. Thorpe advocated strongly that factories should not neglect the fabrication of spare parts in the turmoil of production of complete apparatus. He feels that there is great need of a suitable system of training mechanics for tractor service work, as it cannot be assumed that a man who can assemble an automobile will make a satisfactory tractor operator. There should be a definite plan to assure that the men making repairs and adjustments in the field are well qualified for the work. Instructions as to assembling and operation should be given to secure a satisfactory fundamental result.

In connection with the development of farm implements and tools of various kinds to be operated by tractors, Mr. Thorpe said that by using the tractor in about a score of different operations it would be possible by spreading the overhead, which is the largest item of expense, to reduce the cost of plowing 30 per cent. The actual needs of the farmer should be kept in mind at all times. With relation to the use of motor trucks in farm work, the speaker was of the opinion that sufficient specific data as to cost of operation for comparison with horsedrawn haulage are lacking, and that a standard method of demonstrating the performance of tractors and trucks should be worked out on an engineering basis, for the reason that salesmen cannot proceed intelligently without proper performance records. Both tractors and trucks should be sold on the basis of fitness.

In conclusion, Mr. Thorpe urged continued consideration of the subject of accessibility of parts in tractor design, the use of better materials, reduction of weight and the furtherance of a program to increase the number of tools driven by tractors in farm work. His remarks were heartily applauded.

The Need for Greater Service Accessibility in Car Design was treated by T. F. Cullen, managing editor of the *Automobile Trade Journal*. Mr. Cullen was formerly engaged in passenger-car service work and it is

not surprising that his comprehensive discussion elicited much interest. Starting with the axiom that everything done to reduce upkeep and maintenance cost tends to increase the car owner's satisfaction, items of expense were listed as follows in descending value: insurance, garage expense, repairs and adjustments, tires, gasoline and oil. Service reputation based on the cars now in use is rapidly becoming the predominating factor in resales. With 8,000,000 cars in use today the reduction of time necessary for service work by 2 hr. per car per year would make possible a saving of total upkeep expense per year of $15,000,000, in Mr. Cullen's opinion. In the preparation of his paper, the author made a survey of 40 cars representative of various schools of design, including those equipped with 4, 6, 8 and 12-cylinder engines and covering a wide price-range. He then rated the cars according to comparative accessibility in 25 different service operations, no attempt being made to cover all operations or extensive overhauls. On a basis of a par of four for each operation, Mr. Cullen rated the cars in percentages varying from 64 to 95, according to his view as to what the respective accessibilities should be; the percentage for engines with cylinders in a row being 83 as against 69 for V-type engines. In the last named connection it was pointed out that factors not related directly to service work must be taken into account in determining the all-around desirability of any passenger-car type of engine. L. H. Stellman, chief engineer of the H. H. Franklin Mfg. Co., expressed the opinion that in view of the omission of some service operations from Mr. Cullen's chart, the total percentages derived by him were somewhat misleading. Mr. Stellman offered the following points for consideration: Dividing parts to be lubricated into (*a*) engine, (*b*) fast-moving or heavy-duty, and (*c*) minor, such as brake-rods; all nuts and bolt-heads to be hexagon-shaped and mounted with sufficient clearance for use of commercial socket-wrenches; cap-screws to be sufficiently strong to withstand abuse in removal and reinstallation quickly and without undue care; where gaskets are used to prevent oil leakage, cap-screws to be sufficiently close together for an average mechanic to get a tight joint and freedom from bulging due to excessive tightening of cap-screws; readily replaceable felt washers in the front and rear wheels; localization of wear on small relatively inexpensive and easily replaceable parts; use of bushings or simple parts of low cost to take wear; arranging wiring so that it can be checked readily, preferably to have all wiring connected with central switchboard; and easy adjustment of transmission and rear-axle bearings, with quick reassembly without consequent oil leakage.

Mr. Cullen dwelt at some length upon the value of factory engineers giving attention to the design of special tools and equipment for dealers' service stations, to facilitate service work on new and old cars. The time is rapidly approaching when the factory engineering department will consider service station equipment for the cars they build just as necessary as assembly equipment and machine tools for the factory. The service man should be consulted in connection with car design, inasmuch as he meets the car owners and knows their needs better than the designing engineer can know them under ordinary circumstances. Some factories have made it compulsory that engineers responsible for the design of a new car shall drive the car during the period of its development and do all necessary work on it themselves, the idea being that the lessons learned in this way should be used in improving the design.

President Beecroft described the "fixed-price" service system now being used more or less extensively in Wisconsin, whereby a car owner calling at a service station is apprised definitely what the shop charge will be before any adjustment or repair work on the car is done. Feeling that this is a step in the right direction, he said that the engineer should go out into the field for the purpose of interpreting and translating for his use the conditions of the environment in which the apparatus he designs works. It is his function to study conditions and meet them economically.

The dinner held on the evening of Feb. 2, which was attended by over 500 members and guests, was highly enjoyable and very instructive. In introducing First Vice-President H. L. Horning, who acted as toastmaster, President Beecroft called attention in a forceful manner to the importance of the work of the Society as evidenced by its personnel and exemplified in its great activities centered about the internal-combustion engine, in the design and production of passenger cars, motor trucks, tractors, house lighting apparatus, stationary engines, motorboats, motorcycles and aircraft.

Mr. Horning made a plea for a more complete realization that basic worth of character is the world's greatest asset and that no individual can hope to survive industrial difficulty unless he has that personal integrity upon which every business man must depend. In connection with research, he said that the man who is not sufficiently versed in physics, chemistry and thermodynamics to locate and understand the things that are causing difficulty in his work will fail; that the firm that makes good will be the firm that knows the job through and through.

President H. H. Merrick of the Great Lakes Trust Co., Chicago, was in his best vein. He said that bankers, being dealers in credit, are necessarily optimists and have faith in the great business structure of the country. He described an optimist as a man who sees in the darkness a light that may not exist; a pessimist as a man who comes along and blows the light out. The future lies in the working of the one fixed law of supply and demand, which was disturbed during the war and much impeded during the period immediately following the armistice. The proof of our nation's strength is that it suffered so little fatal damage in the unprecedented industrial strain which began last spring. Mr. Merrick expressed the view that Roosevelt was right when he said that we would be as unprepared for peace as we were for war. The crying need now is courage. Our entire surplus stock of commodities is not sufficient to replenish the empty shelves of the world. The one thing needed is restoration of worldwide credit.

Prof. J. Paul Goode, of the University of Chicago, gave a masterly address on America as a World Power, presenting many novel charts bristling with statistics that brought home in a very vivid manner the amazing potentialities of this country and the tremendous individual and national responsibilities involved therein. It is pretty certain that few if any of the members ever witnessed such an array of coordinated facts in chart form relating to the wealth and commerce of this country from its inception. Professor Goode said that America is great enough to be generous and wise enough to be just, and expressed the hope that our great opportunities and powers will be used henceforth in such manner that we shall deserve the respect and gratitude of all men for all time.

The $14,000,000,000 trade of the United States last year was the largest in its history. The eastern part of

the United States produces enough to buy in very large volume from the rest of the world. How rich this country is is not known. In 1914 our wealth was estimated at $250,000,000,000. We have the major portion of the significant minerals of the world. We make two-thirds of the world's cotton. War cannot be waged without cotton; a 16 in. gun takes one bale for one shot. We produce no silk, although we are the largest buyers, manufacturers and users of it. We have over one-half of the minable coal of the world.

Professor Goode said that there are four nations that can wage a world war: United States, Great Britain, Germany, and China, potentially; and that any two of them can prevent such a war. War cannot be waged without copper, of which the United States is the principal source of supply.

The musical program of the dinner was of a high order of merit and satisfaction, consisting of classical and popular pieces rendered by the men and boy choir, and the singing by all present of old and modern ditties, the words of which were flashed on screens in three different quarters of the room.

FEBRUARY COUNCIL MEETING

THE meeting of the Council held at Chicago on Feb. 3 was clearly as important as any session of officers of the Society during its whole history. Those taking part in the deliberations were President Beecroft, First Vice-President Horning, Second Vice-Presidents Bachman, Crane, Johnston, Menges and VanBlerck, Councilors Brush, Germane and Pope, Treasurer Whittelsey; Dr. H. C. Dickinson, Past-President Alden and Prof. O. C. Berry of the Research Committee; Vice-Chairman Chryst of the Standards Committee; Chairman Scott of the Meetings Committee, and Secretary and General Manager Coker F. Clarkson.

MEMBERSHIP

Forty-two applications for membership and enrollment were approved, 1 for Service Member, 12 for Member, 20 for Associate, 7 for Junior and 2 for Student Enrollment. Albert deBeaulieu and V. C. Worden were transferred from Associate to Member grade and Harry J. Marx from Junior to Associate grade.

Seventy-one applications for membership were received during January of this year, as compared with 68 for the same month of 1920.

STANDARDS MATTERS

Questions involving the continuance and establishment of Divisions of the Standards Committee, the appointment of personnel of the Divisions and the designation of the Chairmen thereof, were acted upon as set forth in the article appearing in this issue on the 1921 Standards Committee. In addition, consideration was given to the official list of items of work of the Standards Committee, including assignment of new subjects. A report on the number of Division meetings held during the 1920 administrative year and the attendance at and results of these meetings was made.

SECTION MATTERS

The establishment of a Section of the Society with headquarters at Dayton, Ohio, was authorized.

RESEARCH WORK

After receiving a report from the Research Committee and an extended discussion, it was decided that a Research Department of the Society should be instituted, the cost of the conduct of this during the 1921 Administrative Year not to be in excess of $30,000. The purpose in mind in the formal inauguration of this department is outlined elsewhere in this issue of THE JOURNAL

Vice-Chairman Strickland, of the Standards Committee, was designated to serve on the special committee of the Society which works jointly with a committee of the National Automobile Chamber of Commerce in conference with the Underwriters' Laboratories on the elements and features of automobiles in connection with allowance schedules relating to the amount of premiums of theft, collision and fire insurance policies.

PRICES OF PUBLICATIONS OF THE SOCIETY

The following revised schedule of prices for publications of the Society, to non-members and for extra copies to members, was determined upon:

	First Copy		Additional Copies	
	Members	Non-Members	Members	Non-Members
JOURNAL	Paid with dues	$0.50	$0.25	$0.50
TRANSACTIONS (per part)	Gratis	10.00	5.00	10.00
Roster	Gratis	2.50	0.50	2.50
S. A. E. HANDBOOK				
Vol. I	Gratis	10.00[1]	10.00[1]	10.00[1]
Vol. II[2]	....	....	....	....
Data Sheets	....	0.06	0.06	0.06
Binders (each)	3.50	4.00	3.50	4.00
Iron and Steel Pamphlet	....	1.50	1.50	1.50
Nomenclature Pamphlet	....	0.75	0.75	0.75
Engine Testing Forms[3] (per sheet)	....	0.03	0.02	0.03
Emblems	3.50	....	3.50	....
Preprints	0.25	0.50	0.25	0.50

[1]Price does not include any new and superseding sheets. These may be purchased at 6 cents a sheet as issued.
[2]Price for Vol. 2 of the Handbook not to be decided until publication of revised edition.
[3]Now reproduced in Handbook. Special price on orders for 50 or more copies of any standards publication.

SEMI-ANNUAL SOCIETY MEETING

It was formally decided that the next meeting of the Society should be held at West Baden Springs Hotel, West Baden, Ind., May 24 to 28.

LONG-DISTANCE FLIGHT

ASIDE from the exploratory value of long-distance reconnaissance flights, there is a very material military value. Experience and training impossible of attainment by any other means is to be had. Pilots and mechanics who participate in such flights carry on operations thousands of miles from their base. Every long-distance flight ever attemped has given the flying personnel engaged a wonderful opportunity to study the art of flying. It affords the best opportunity to check the value of navigating instruments. Every flight has its own individual problems involving mechanical operation, supply and navigation. The successful solution of all these problems is the best possible training for Air Service personnel. Practice flying around an airdrome is essential, but however important such flying may be, it cannot compare in any way with long-distance cross-country flying. These flights already successfully carried out have done more than any one thing to foster and develop commercial aviation.
—Air Service News Letter.

The Nature of Flame Movement in a Closed Cylinder

By C. A. Woodbury[1], H. A. Lewis[2] and A. T. Canby[2]

Annual Meeting Paper *Illustrated with* Charts and Photographs

THE nature of flame propagation in an automobile engine cylinder has, for some time, been the subject of much discussion and speculation. However, very little experimental work has been done on flame movement in closed cylinders with the view of applying the knowledge directly to the internal-combustion engine. Recently automobile builders and others have seen the production of automobiles, trucks, and tractors increase at a rate out of all proportion to the increase in the production of the vital fuel, gasoline. With the recognition of this attention was turned to the possibilities of (*a*) using other fuels such as kerosene, benzene, and alcohol and (*b*) increasing the efficiency of the engine when using the existing standard fuel. To accomplish either of these ends information on the flame propagation characteristic of each of these fuels was essential.

It has become very generally recognized that there is one great difficulty; namely, "knocking" which attends the use of higher-boiling paraffin hydrocarbons, such as kerosene, and that "knocking" is one of the major difficulties to be overcome in designing higher compression, and hence more efficient engines. It was desirable, therefore, to determine if possible the nature and cause of fuel knock. The work described in this paper was undertaken to determine the characteristic flame movement of these various fuels and the physical and chemical properties which influence this flame propagation.

Scope of Work.

The program which was originally decided upon assumed that a knowledge of flame movement at atmospheric temperature and pressure should be studied first. It was then proposed to determine

(1) The influence of turbulence or movement of the gas at the moment of ignition
(2) The influence of temperature
(3) The influence of pressure or density
(4) The influence of the shape of the explosion chamber
(5) The influence of the position and number of ignition points, together with the importance of the intensity of the ignition

It was assumed that a clear understanding of the above factors as affecting one fuel should be gained before attempting a comparison of the different fuels. To simplify the work a permanent gas, acetylene, was selected for the development of methods of testing and for preliminary experiments. The experiments outlined in this paper represent only a preliminary survey of the factors included in the above outline. It is hoped that future work will give more exact information regarding the effect of these several variables. In addition to the experimental work on flame propagation a comprehensive study of the literature bearing on the subject has been made. Considerable attention is given in this paper to the discussion of the results so found.

After a general survey of the methods of measuring flame propagation which have been used by various investigators, it was decided to use the photographic method chiefly for the reason that, if successful, it would disclose the rate and character of the movement of the flame at any point over the entire exposed distance of travel. To eliminate as many variables as possible in preliminary work a cylinder of constant volume without moving piston was chosen for the explosion chamber.

Naturally many difficulties were encountered in the development of the apparatus. Chief among these were

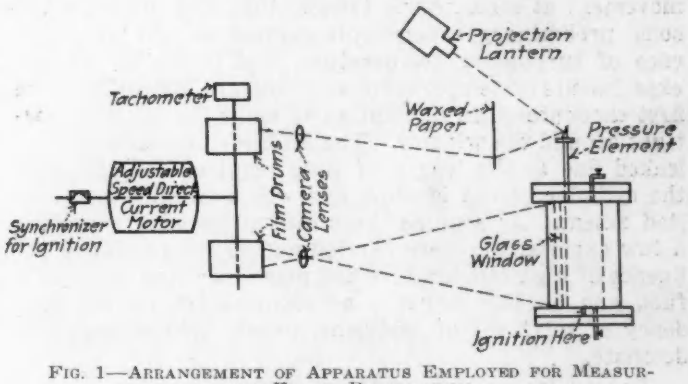


Fig. 1—Arrangement of Apparatus Employed for Measuring Flame Propagation

(*a*) lack of sufficient light from the flame at all times to reproduce itself properly on the film and (*b*) the construction of a gas-tight seal around the window of the explosion cylinder. The apparatus and method at its present stage of development are essentially as follows:

The explosion chamber at the right of the Fig. 1 is a cylinder 4 in. in diameter and 12 in. long, inside measurements, provided with a ¾-in. glass rod extending the entire length as a window. High-pressure needle valves are inserted in the top and bottom of the cylinder for introducing the gas charge and sweeping out the products of combustion. The gas is ignited by a standard spark-plug in the center of the lower end of the cylinder. A Midgley pressure element[3] is inserted in the top of the cylinder, the beam of light from the mirror of the pressure indicator being focused on a wax paper screen and reproduced on a film on the upper of two rotating drums. The light from the flame in the cylinder passes through a camera lens to another film on the lower rotating drum. The two drums are mounted on the same shaft which is driven by an adjustable-speed direct-current motor so that drum speeds of from 100 to 4000 r.p.m. can be obtained. The speed is measured by a combined revolution counter and stop-watch mounted on the end of the shaft. Ignition of the gas charge is synchronized with definite needle points on the film drum through a special sparking device on the

[1]Director, Eastern laboratory, E. I. du Pont de Nemours & Co., Chester, Pa.

[2]Research chemist, Eastern laboratory, E. I. du Pont de Nemours & Co., Chester, Pa.

[3]See The Journal, December, 1920, p. 491.

rear of the driving motor. The apparatus thus gives a direct measurement and comparison of the rates of flame movement and pressure development from a definite ignition point. The fastest film on the market was inadequate for the purpose at hand. It was known from the work of the Bureau of Chemistry that great possibilities lay in the use of the so-called photo-sensitizing dyes for increasing the sensitiveness of emulsion to light of long wave-length. After consultation with the Bureau pinacyanol was selected and used very successfully.

In the course of the development of this apparatus, acetylene-air mixtures were exploded because of the high actinic properties of the flame. During this development

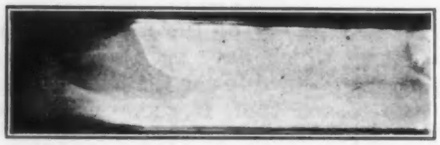


Fig. 2—Photograph of the Flame Movement in a Mixture Composed of 10 Per Cent of Acetylene and 90 Per Cent of Air Having an Initial Temperature of 25 Deg. Cent. (77 Deg. Fahr.), and a Pressure of 1 Atmosphere

period results were obtained on the nature of the flame movement at atmospheric temperature and pressure and some preliminary experiments carried out on the influence of turbulence, temperature, and pressure. In the experiments on temperature and pressure difficulties were first encountered in attempting to make the cylinder gastight around the window. The Midgley pressure element leaked due to the length of time required for charging the cylinder before ignition and was used only to a limited extent. As soon as these difficulties were overcome a few experiments were carried out on the combined influence of high temperature and pressure using ether as a fuel, and on the influence of temperature on the tendency of mixtures of acetylene, oxygen and nitrogen to detonate.

Flame Movement at Normal Temperature and Pressure

Previous investigators of the nature of flame movement at ordinary temperatures and pressures in closed vessels have confined their observations almost entirely to pressure and temperature measurements rather than to flame propagation. Although little information is available concerning the actual flame movements, the rate

Fig. 3—Photograph of the Flame Movement in a Mixture Composed of 20 Per Cent of Acetylene and 80 Per Cent of Air Having an Initial Temperature of 25 Deg. Cent. (77 Deg. Fahr.) and a Pressure of 1 Atmosphere

of flame propagation is indicated with fair accuracy by the rate of pressure development within the explosion bomb, and on this basis considerable data have been collected. The point of agreement between the rate of flame propagation and development of pressure accepted by all investigators is that the instant of total inflammation of the gas concurs with the instant of maximum pressures. This fact is substantiated by the experiments of R. V. Wheeler[4] in which close agreement was shown between the rates of flame propagation of various mixtures of methane and air when calculated from actual measurements of the rate of flame movement and from the period required for the development of maximum pressure in two spherical bombs of different capacity.

Early investigators assumed that the instant of ignition coincided with the first appearance of pressure on the indicator or gage. Bairstow and Alexander[5] however have shown that this was not the case, and that after ignition an appreciable period of time elapses before a pressure record can be obtained. Experiments by J. D. Morgan[6] indicate that the inflammation of a gaseous mixture is practically instantaneous with the passage of the igniting spark. It may, therefore, be concluded that the interval of time between ignition and the appearance of pressure is due to a lag in the indicators, or to cooling effect of the base and walls of the vessel. R. V. Wheeler[4] has studied this period using various mixtures of methane and air ignited at the center of spherical bombs and has calculated that approximately one-fifth of the total volume of gas is inflamed before pressure is first recorded.

In our experiments at atmospheric temperature and pressure, mixtures of acetylene and air varying from 5 to 20 per cent of acetylene were exploded in the cylinder and the movement of the flame photographed. A general idea of the velocities of flame movement attained with these mixtures can be obtained from the results given in Table 1.

TABLE 1—VELOCITIES OF FLAME MOVEMENT IN AIR-ACETYLENE MIXTURES

Composition of Mixture		Velocities Attained			
		Maximum		Average	
Acetylene, per cent	Air, per cent	Meters per sec.	Ft. per sec.	Meters per sec.	Ft. per sec.
5	95	9.10	29.86	4.05	13.29
6	94	.....	.....	6.05	19.85
8	92	38.00	124.67	12.50	41.01
10	90	25.00	82.02	15.00	49.21
15	85	20.80	91.86	8.10	26.57
20	80	9.20	36.09	4.00	13.12

As disclosed by previous investigators, the velocity was relatively low for lean and for rich mixtures showing the maximum for the mixtures containing from 8 to 10 per cent of acetylene.

We are not, however, so concerned with the actual velocities of flame movement as we are with the nature of the movement. Typical photographs of the flame movement for the 10 per cent acetylene mixture and for the slow mixture, such as the 20 per cent, are reproduced in Figs. 2 and 3 respectively. In these photographs the film should be considered as moving from right to left and the flame from the bottom to the top. The exceedingly slow initial movement of the flame followed by gradual acceleration is apparent. After the flame has traveled approximately two-thirds the length of the cylinder it suddenly stops. The movement is soon resumed, however, and the flame proceeds slowly to the top of the bomb.

In the case of the 10 per cent mixture there are successions of alternate dark and light vertical bands in the secondary burning period which first become perceptible at the point at which the flame front is arrested. This is also true with the mixtures which gave relatively high velocities. These bands have a slight pitch apparently

[4]See *Journal of the Chemical Society* (England), vol. 113, p. 840.
[5]See *Proceedings of the Royal Society of London*, vol. 76A, p. 340.
[6]See *Engineering*, Oct. 24, 1919, p. 535.

indicating a vibration with the approximate velocity of sound at the temperature. It is notable, however, with mixtures of low velocity, for example, 20 per cent of acetylene, that these vibrations are not present.

One naturally is particularly interested in why the flame comes to rest after traveling a certain distance; also what is responsible for the vibrations exhibited in the relatively fast mixtures. Before offering an explanation of these phenomenon, it is first necessary to consider the rate of pressure development in these experiments as compared with the rate of flame movement.

It will be noted from a comparison of Figs. 4 and 5 that the curves showing the flame movement and the pressure development have the same general form, and that there is an arrest in the pressure development corresponding to the arrest in the flame movement. The time in Fig. 5 is calculated from the point of initial pressure and not from ignition of the charge. Fig. 6, giving the time relations from the ignition of the charge, shows that no

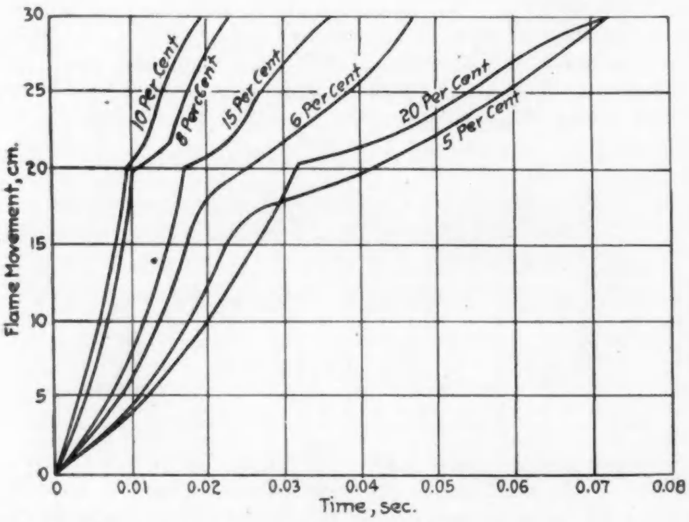


Fig. 4—Flame Movement in Mixtures Containing Varying Percentages of Acetylene

pressure was recorded until the flame had traveled approximately 25 per cent of the length of the bomb. This is in agreement with the findings of previous investigators. It will also be noticed that the arrest in the pressure development occurred at approximately the same time as the arrest in the flame movement. The time of maximum pressure coincides with the time of total inflammation, as had been reported by previous investigators.

Fig. 6 shows also that at the time of the flame and pressure arrests the flame has propagated two-thirds of the length of the bomb whereas only one-quarter of the total pressure has been developed, and that after the arrest the flame in traveling a comparatively short distance produced a very much greater increase in pressure. This is due, it is felt, to the fact that during the burning the expansion of the hot gases behind the flame pushes the flame front forward and compresses the unburned gas ahead of the flame front. Thus, in its propagation the flame is continually entering a gas of higher density which, when burned, naturally produces a greater increment in pressure.

This brings us to a new factor which probably plays a

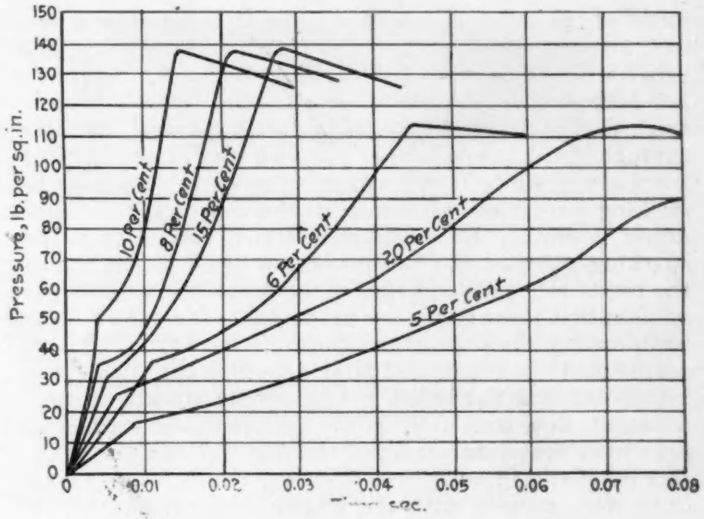


Fig. 5—Curves of Pressure Development in Mixtures Containing Varying Percentages of Acetylene

very important part in determining the rate of flame movement in closed cylinders.

According to Haward and Sastry[7], the rate of flame propagation during the so-called uniform movement period for an 8.9 per cent mixture of acetylene with air is approximately 3.12 meters per sec. (10.24 ft. per sec.). This figure applies to experiments where the influence of pressure behind the flame front did not exist. In our experiments in a closed cylinder mentioned above, an 8 per cent acetylene-air mixture during the uniform movement period attained a velocity of 38 meters per sec. (124.68 ft. per sec.) or 12 times that reported by Haward and Sastry. Apparently the expansion of the hot gases behind the flame front exerted a great effect upon the rate of propagation. It is felt that this factor of expansion of the burned gases is of great importance in the consideration of the flame movement in closed cylinders.

With a realization of the characteristic nature of the pressure development ahead of the flame front and the

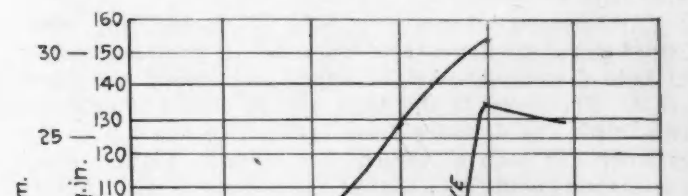


Fig. 6—Curves of Flame Movement and Pressure Development in a Mixture Composed of 10 Per Cent of Acetylene and 90 Per Cent of Air Having an Initial Temperature of 25 Deg. Cent. (77 Deg. Fahr.) and a Pressure of 1 Atmosphere

[7]See *Journal of the Chemical Society* (England), vol. 111, p. 841; vol. 116, p. 578.

effect of the expanding burned gases it is possible to present an explanation of the flame arrest and the vibrations exhibited by relatively fast burning mixtures. So far as has been determined, Dixon[8] was the first investigator to learn that in a closed tube flame does not travel smoothly through the entire column of gas, and that after traveling for some distance it practically stops as if struck by or striking something. Dixon holds the view that this flame arrest is due to the sound wave which travels from the sparking point at the bottom of the bomb to the top of the bomb, rebounds and strikes the flame front. It is our opinion that these waves are produced by the arrest of the flame rather than being the cause of the arrest. In experiments to be mentioned later, in which turbulence was introduced into the bomb, practically no vibrations were apparent, due, it is felt, to the fact that the turbulence prevented the sharp arrest of the flame movement. Furthermore, it will be noticed in Figs. 2 and 3 that vibrations were present with the 10 per cent gas and absent with the 20 per cent gas, due presumably to the great difference in the sharpness of the arrest. The igniting spark was of the same intensity in all cases. Dixon's own photographs show that vibrations are not present except when there is flame arrest.

It is our theory that it is the high density of the gases ahead of the flame front which arrests the forward movement of the flame. Just why the flame stoppage is sudden rather than a gradual slowing down, as the pressure accumulates ahead of the flame front, is not wholly understood at this time. It is evident that during the entire travel of the flame, the gases approach a state of pressure equilibrium throughout the cylinder and the attainment of this equilibrium is hindered by the fact that the gases are not perfectly elastic. It has been previously shown that the flame front is pushed forward by the expansion of the burned gases and that the unburned gases are compressed to a high density at the same time. Obviously a point can be reached at which the pressure due to the temperature behind the flame is equalled by the pressure due to the density ahead of the flame. At that point the flame front is no longer pushed forward; the propagation is arrested.

Furthermore, when such a point is reached, any burning of gas at the flame front will exert its pressure equally in both directions; that is, ahead and behind the flame front. The arrest in the flame usually occurs after about two-thirds the distance from ignition to the top of the cylinder has been traversed; the volume of the burned gas is then about twice that of the unburned gas. Applying equal pressure to these two unequal volumes obviously causes a greater linear contraction in the larger volume, or the burned gas. A recession of the flame front would be expected under such conditions. In some fast burning mixtures the flame front does recede immediately after the arrest. After the arrest or recession of the flame front, the forward movement is resumed, and a high density again built up ahead of the flame. This cycle of alternate arrest and resumption of the flame movement causes, in our opinion, the vibrations in the burning gases. It is recognized that other factors, such as the temperature and its effect on the elasticity of the gases, and the actual momentum of the forward moving flame, affect the arrest in the flame front. It is felt, however, that high density gas ahead of the flame front is the most important influence.

Influence of Turbulence

The decided increase in the rate of flame propagation due to mechanical agitation of the gaseous mixture was first noted by Schloesing and de Mondesis[9] in 1864, and was described by Mallard and Le Chatelier. This information was apparently forgotten until Clerk and Hopkinson's[10] investigation of 1912. Since that time numerous investigators[11] have studied turbulence, establishing that the speed of burn is increased but the ignition rendered more difficult by agitating the gases.

Some very interesting results have just been published by Mason and Wheeler[12]. A tube 2.15 cm. (0.83 in.) in diameter and 220 cm. (85.53 in.) long was fixed horizontally. Streams of methane and air could be passed at different speeds along the tube, both ends of which were open. The mixtures were ignited electrically at a point 26 cm. (10.24 in.) from one end of the tube and the speeds of the flames were measured by screen wires, the first screen wire being 50 cm. (19.69 in.) from the point of ignition. A mixture containing 6.35 per cent of methane was used and the results given in Table 2 obtained.

TABLE 2.—FLAME SPEEDS IN AIR AND METHANE

Speed of Current of Air and Methane		Speed of Flame	
Cm. per sec.	In. per sec.	Cm. per sec.	In. per sec.
Nil	Nil	287	112.99
23	9.06	582	229.13
43	16.93	952	374.80
75	29.53	1,527	601.18

These results show that a comparatively gentle movement of the mixture as represented by a speed of 23 cm. per sec. (9.06 in. per sec.) nearly doubles the speed of the flame.

In our experiments a study was made of the effect of turbulence at atmospheric temperature and pressure. This study was on 10, 15 and 20 per cent acetylene-air mixtures. Varying degrees of turbulence were obtained by rotating a fan at different speeds, this fan being placed within the bomb at a point approximately equidistant from the two ends. Tests were made first with the fan at rest and then revolving at speeds of 1100, 2200, 3300 and 4400 r.p.m. Typical photographs are shown in Figs. 7 and 8, the former with the fan present but not revolving, and the latter with the fan revolving at 3300 r.p.m. These should be compared with Fig. 2 which was made without the fan being present.

An interesting point to be noted in comparing Figs. 2 and 7 is, that the mere presence of the fan changes the character of the flame arrest. There is a decrease in rate, but this is gradual rather than sudden.

In all of the experiments with the fan revolving, the nature of the flame movement was similar to that shown in Fig 8. It was apparent that although turbulence seemed to interfere with the accumulation of the pressure ahead of the flame front thereby eliminating a sudden arrest and although the distance of smooth accelerated flame travel was increased with increase in turbulence (See Fig. 9), nevertheless the flame movement did slow down in all cases as it approached the top of the bomb. It is recognized, however, that still greater turbulence than obtained in our experiments, or other types of gas agita-

[8]See *Journal of the Chemical Society* (England), vol. 99, p. 594.

[9]See *Annales des Mines*, Series 8, vol. 4, p. 298.

[10]See *Engineering*, July 11, 1913, p. 61.

[11]See Report of the British Association for the Advancement of Science for 1912, p. 201, and the *Journal of the Chemical Society* (England), vol. 115, p. 181.

[12]See *Journal of the Chemical Society* (England), vol. 119, p. 578.

tion than that used, might have given continually accelerating rates of propagation through the entire column of gas.

An idea of the effect of turbulence on the actual speed of the flame movement is given in Table 3. These results show that the slower the rate of propagation in the mixture without turbulence, the greater the effect of turbulence on that rate.

TABLE 3—INFLUENCE OF TURBULENCE ON THE VELOCITY OF FLAME MOVEMENT IN ACETYLENE-AIR MIXTURES

Acetylene, per cent / Air, per cent	Composition of Mixture 10 / 90		15 / 85		20 / 80	
Speed of Fan, r. p. m.	Average Velocity					
	Meters per sec.	Ft. per sec.	Meters per sec.	Ft. per sec.	Meters per sec.	Ft. per sec.
At Rest	15.0	49.21	8.1	26.57	4.0	13.12
1,100	21.3	69.88	17.5	57.41	6.9	22.64
2,200	25.0	82.02	19.8	64.96	10.7	35.11
3,350	29.6	97.11	24.5	80.38	14.9	48.88
4,400	38.9	127.62	30.4	99.74	20.6	67.63

Although the results obtained to date are of a preliminary nature, they indicate the tremendous influence of turbulence on the rate of flame propagation and the im-

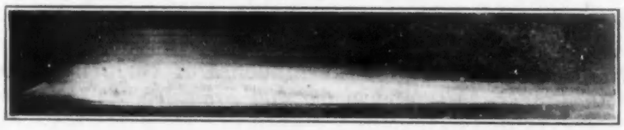


FIG. 7—PHOTOGRAPH OF FLAME MOVEMENT IN A MIXTURE COMPOSED OF 10 PER CENT OF ACETYLENE AND 90 PER CENT OF AIR HAVING AN INITIAL TEMPERATURE OF 25 DEG. CENT. (77 DEG. FAHR.) AND A PRESSURE OF 1 ATMOSPHERE

When This Photograph Was Taken the Fan Which Was Placed within the Bomb to Produce Turbulence Was Not Rotating. This Illustration Should Be Compared with Fig. 2 on Page 210, Which Was Taken Before the Fan Was Placed in the Bomb

portant relation which a complete knowledge of the nature and direction of the flow of gases bears to the design of internal-combustion engines.

Influence of Temperature and Pressure on Propagation

Several investigators have made statements which indicate that increased initial temperatures increase the rate of flame propagation and it seems entirely reasonable to expect such behavior. However, the study of temperature effect has been greatly neglected in the past and few actual experimental data are available. Our work on increased temperature at constant pressure was carried out on mixtures varying from 8 to 20 per cent of acetylene in air at temperatures from 25 to 125 deg. cent. (77 to 257 deg. fahr.). With a 10 per cent acetylene-air mixture at 25 deg. cent. (77 deg. fahr.) an average velocity of 15 meters per sec. (49.21 ft. per sec.) was obtained; at 50 deg. cent. (122 deg. fahr.), 12.2 meters per sec. (40.03 ft. per sec.); at 70 deg. cent. (158 deg. fahr.), 10.8 meters per sec. (35.43 ft. per sec.); and at 80 deg. cent. (176 deg. fahr.), 10.35 meters per sec. (33.96 ft. per sec.). The maximum velocity attained was practically unchanged over this range of temperature. With richer mixtures containing 15 and 20 per cent acetylene there was an apparent increase in rate of propagation with increase of temperature from 25 to 75 deg. cent. (77 to 167 deg. fahr.), and then a decrease in rate

[13]See the Gas Petrol and Oil Engine by Dugald Clerk, vol. 1, p. 166.

FIG. 8—FLAME MOVEMENT IN A MIXTURE COMPOSED OF 10 PER CENT OF ACETYLENE AND 90 PER CENT OF AIR HAVING AN INITIAL TEMPERATURE OF 25 DEG. CENT. (77 DEG. FAHR.) AND A PRESSURE OF 1 ATMOSPHERE

When This Photograph Was Taken the Fan Which Was Placed in the Bomb to Produce Turbulence Was Revolving at 3300 R.P.M.

on further rise to 125 deg. cent. (257 deg. fahr.). Difficulty was encountered in obtaining pictures at the higher temperatures, as the lowered density of the gas greatly diminished the available amount of light. It is possible that this decrease in density of the gas by dispersion may have counteracted any increase in rate of propagation due to increase in initial temperature. The results obtained indicated that increased temperature produced little effect upon the rate of flame propagation. The investigation was not carried over a sufficiently wide range of conditions to warrant a final conclusion, however.

The effect of initial pressure on the rate of flame propagation may be more easily studied than that of initial temperature, for pressure variations may be made independent of temperature changes. The results available are, therefore, more definite. Very high initial pressure apparently produces no material increase in the rate of flame propagation. This is brought out by the work of Peteval described by Dugald Clerk.[13] In his experiments Peteval measured the rate of pressure development and, therefore indirectly, the rate of flame propagation of a mixture of coal gas and air compressed to an initial pressure of 1100 lb. per sq. in. It was found that the time required to attain maximum pressure was almost identical with that required by the same mixture when fired at atmospheric pressure.

In our attempts to study the effect of pressure on the rate of flame propagation, considerable difficulty was en-

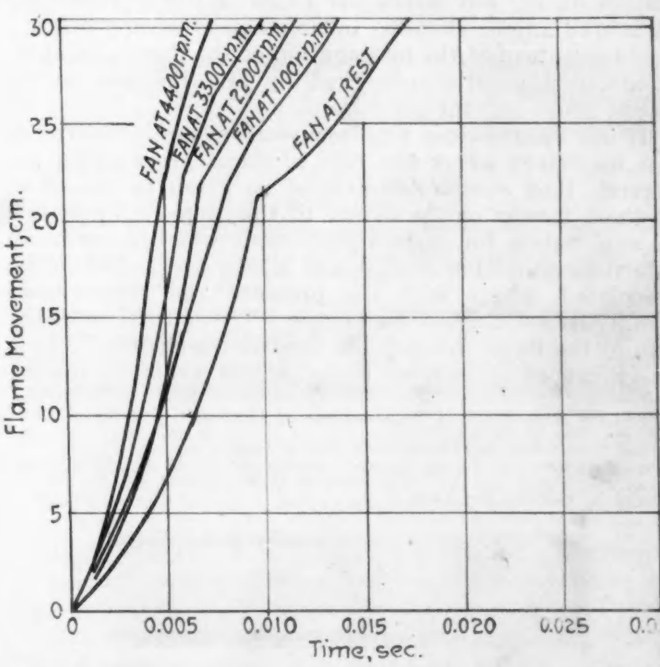


FIG. 9—TURBULENCE EFFECTS ON A MIXTURE COMPOSED OF 10 PER CENT OF ACETYLENE AND 90 PER CENT OF AIR HAVING AN INITIAL TEMPERATURE OF 25 DEG. CENT. (77 DEG. FAHR.) AND A PRESSURE OF 1 ATMOSPHERE PRODUCED BY ROTATING THE PRESSURE FAN AT VARIOUS SPEEDS

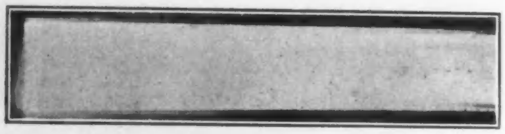


FIG. 10—TYPICAL PHOTOGRAPH OF A DETONATION OBTAINED IN A MIXTURE CONSISTING OF 20 PER CENT OF ACETYLENE, 29.6 PER CENT OF OXYGEN AND 50.4 PER CENT OF NITROGEN HAVING AN INITIAL TEMPERATURE OF 25 DEG. CENT. (77 DEG. FAHR.) AND A PRESSURE OF 1 ATMOSPHERE

countered in keeping the bomb gas-tight, and the results cannot be presented as conclusive evidence at this time. The results obtained on various mixtures of acetylene and air under initial pressures of from one to four atmospheres, indicated that with each gas mixture the rate of propagation increases with an increase in the initial pressure up to a critical density and that with any further increase in the pressure above that critical value no increase in the rate of propagation is obtained. The critical density in most cases is two to three atmospheres. Similar results, described below, are reported by Dixon on the effect of pressure on the velocity of the detonation

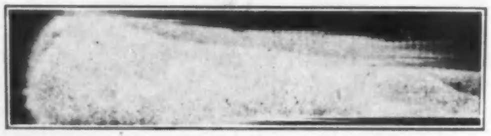


FIG. 11—PHOTOGRAPH OF A MIXTURE OF 20 PER CENT OF ACETYLENE, 32 PER CENT OF OXYGEN AND 48 PER CENT OF NITROGEN SHOWING THE OCCURRENCE OF DETONATION JUST BEFORE THE FLAME REACHED THE TOP OF THE BOMB
The Mixture in This Case Had an Initial Temperature of 25 Deg. Cent. (77 Deg. Fahr.) and Was Subjected to a Pressure of 1 Atmosphere

wave. A consideration of the information at hand indicates that increased initial pressure does not materially affect the rate of flame propagation. It must be understood, of course, that these statements apply only to the effect of temperature and pressure on the rate of propagation during any particular phase of flame travel; for it is well known that the inflammability of any mixture and the nature of the propagation of the flame through a mixture is greatly influenced by any increase in the temperature and the pressure.

If our assumptions that temperature and pressure do not materially affect the rate of flame propagation are correct, then consideration must be given to the effect of these factors on the nature of the propagation to find an explanation for certain phenomena which occur in an internal-combustion engine and which are known to be associated closely with the pressure and temperature conditions existing in the engine. The normal propagation of the flame through the combustion-chamber might be influenced in various ways, as for example, by the development of the detonation wave or by the appearance of autoignition in the unburned gases ahead of the flame front.

In a study of fixed gases such as acetylene, hydrogen, carbon bisulphide and cyanogen, Dixon[14] has established that a considerable distance of flame travel from ignition is necessary before the development of a detonation wave, and that this necessary distance depends upon the fuel, and upon the ratio of fuel to oxygen. For example, the acetylene burn accelerates to detonation in a much shorter distance than does that of hydrogen. Dixon[15] has recently disclosed that he has been studying the development of the detonation wave in mixtures of liquid fuels, such as ether, alcohol, pentane and benzine, in air. No details of the work are given, but ether and alcohol are classed together as able to just propagate detonation, and benzine and pentane are classed together as unable to accelerate to detonation at atmospheric temperature and pressure.

It has been found that the velocity of the detonation wave is decreased by increase in temperature[16] from 25 to 100 deg. cent. (77 to 212 deg. fahr.). A study of both reduced and increased initial pressures has shown that for each gas mixture a critical pressure exists, usually two or three atmospheres absolute, below which the detonation velocity increases with any increase in the pressure, but above which the velocity is practically constant and independent of any pressure increase.

A search of the literature, however, reveals no definite information concerning the influence of various physical factors, such as temperature and pressure, on the development of detonation in the case of any particular fuel-air mixture.

Our work was therefore confined to the identification of the detonation wave as determined by our apparatus and a brief study of the effect of the composition of the mixture of acetylene, oxygen and nitrogen, and of the influence of an increased initial temperature and pressure, on the tendency to develop detonation. An attempt was also made to develop detonation in the case of a badly knocking fuel such as ether, by igniting at a high temperature and pressure. No detonation was obtained in this case and the results are therefore discussed under the subject of autoignition below.

Preliminary work on acetylene-air mixtures showed that the detonation wave could not be set up in the 12-in. cylinder by igniting at atmospheric temperature and pressure. The mixtures were therefore enriched with oxygen. Fig. 10 is a typical photograph of a detonation finally obtained in a mixture containing 20 per cent of acetylene, 29.6 per cent of oxygen, and 50.4 per cent of nitrogen. It may be seen that the flame progresses with an accelerated velocity to a point about 7 in. from ignition at which it attains a very high and apparently uniform rate of travel. This is undoubtedly detonation though no attempt was made to determine the actual detonation velocity.

Fig. 11 which is reproduced from a photograph of a mixture of 20 per cent of acetylene, 32 per cent of oxygen and 48 per cent of nitrogen, shows detonation occurring just before the flame reached the top of the bomb. It is interesting to note that a slight change in the composition of the gas mixture exerts a great influence on the tendency to detonate or on the distance traveled by the flame before detonation was set up.

In studying the effect of the composition of mixtures of acetylene, oxygen and nitrogen on their tendency to detonate, four series of mixtures containing respectively 10, 12, 15 and 20 per cent of acetylene were selected.

[14]See the *Philosophical Transactions of the Royal Society of London*, vol. 200, p. 315.
[15]See THE JOURNAL, December, 1920, p. 521.
[16]See Report of the Bakerian Lecture delivered by Herold B. Dixon, published in the *Philosophical Transactions of the Royal Society of London* for 1893.

FIG. 12—PHOTOGRAPH SHOWING AUTOIGNITION IN A MIXTURE CONTAINING 15 PER CENT OF ACETYLENE, 41 PER CENT OF OXYGEN AND 44 PER CENT OF NITROGEN HAVING AN INITIAL TEMPERATURE OF 25 DEG. CENT. (77 DEG. FAHR.) AND A PRESSURE OF 1 ATMOSPHERE

Amounts of oxygen ranging from less than the amount required to burn the acetylene to carbon monoxide to an excess of the amount required for combustion to carbon dioxide were used in each series. Photographs of the explosions of these various mixtures showed that detonation had been set up in only one case, that of the mixture containing 20 per cent of acetylene and oxygen in the combining proportion to give carbon monoxide. However, it must be pointed out that although detonation was obtained in only one instance, autoignition in the unburned gases ahead of the flame front was exhibited over a wide range of mixtures. Fig. 12 is a typical example of this phenomenon as shown by a mixture containing 15 per cent of acetylene, 41 per cent of oxygen and 44 per cent of nitrogen.

These results have indicated, to our mind, certain rather obvious conclusions, namely

(1) Detonation is most easily initiated in a mixture containing acetylene and oxygen in the combining proportion to give carbon monoxide

(2) The initiation of the detonating wave is delayed by the presence of an inert gas such as nitrogen. Mixtures containing acetylene and oxygen in the proportion given under (1) and more than approximately 50 per cent of nitrogen will not detonate in a 12-in. space at atmospheric pressure and temperature when ignited with a spark of normal intensity

(3) Oxygen in excess of the proportion given under (1) acts as inert gas and retards the initiation of detonation

Although these statements apply directly only to the behavior of acetylene mixtures, the work of other investigators on numerous gases has shown that the presence of inert gases in combustible mixtures inhibits detonation to a marked extent.

The effect of temperature on the tendency of acetylene mixtures to detonate was investigated by firing a series first at atmospheric pressure and temperature, and then at an initial temperature of 125 deg. cent. (257 deg. fahr.) and 10-lb. gage pressure. Figs. 13 to 17, inclusive, present the comparative records obtained with four mixtures fired under these conditions. It is evident that in every case in which the initial temperature of the mixture was raised, the detonation occurs later. It is impossible to state definitely from so few results that an increased initial temperature actually delays the setting up of detonation in a given mixture. However, it is our belief that high initial temperature does not accelerate the initiation of the detonating wave as has recently been suggested.

Autoignition

It is well known that fuel-air mixtures ignite and burn when subjected to compression sufficient to raise the temperature of the mixture to or above its ignition point. As pointed out above, the movement of the flame from ignition compresses the unburned gases ahead of the flame front. This increase in the density of the unburned gases is, of course, accompanied by an increase in the temperature and it is reasonable to assume that these gases could thus be ignited. The behavior of gas mixtures under high compression and the resulting flame movements are therefore of importance.

Dixon[17] has presented the most interesting results on the behavior of gas mixtures at high pressures in an investigation carried out primarily for the purpose of determining the ignition points of gaseous mixtures. Our particular interest is centered on the nature of the movement of the flame in gases ignited under the high temperature and pressure employed. In these experiments the various gas mixtures were compressed by driving a piston into a tube by means of a falling pendulum, thus obtaining extreme conditions of temperature and pressure almost instantaneously. With a mixture of carbon bisulphide and oxygen in the proportion of 1 to 5 the mixture ignited through autoignition. Relatively low velocities of flame movement were obtained even under the highest compressions, and there was no evidence of detonation. An idea of the severity of the tests to which Dixon subjected these explosive mixtures, and the nature of the flame movement, is given in Table 4.

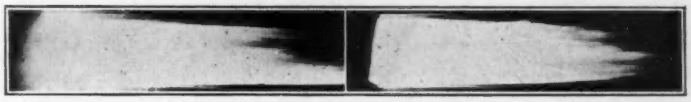


Fig. 13—Results Obtained with a Mixture Consisting of 20 Per Cent of Acetylene, 30 Per Cent of Oxygen and 50 Per Cent of Nitrogen

In the View at the Left the Initial Temperature Was 25 Deg. Cent. (77 Deg. Fahr.) and the Pressure Was 15 Lb. Absolute. In the Other View the Initial Temperature Was Raised to 125 Deg. Cent. (257 Deg. Fahr.) and the Pressure to 25 Lb. Absolute, with the Result That Detonation Was Delayed

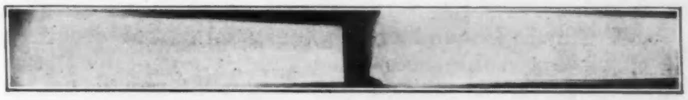


Fig. 14—Results Obtained with a Mixture Consisting of 22.50 Per Cent of Acetylene, 33.75 Per Cent of Oxygen and 43.75 Per Cent of Nitrogen

In the View at the Left the Initial Temperature Was 25 Deg. Cent. (77 Deg. Fahr.) and the Pressure 15 Lb. Absolute. In the Other View the Initial Temperature Was 125 Deg. Cent. (257 Deg. Fahr.) and the Pressure Was 25 Lb. Absolute

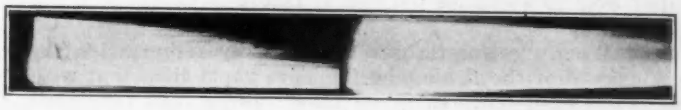


Fig. 15—Results Obtained with a Mixture of 25 Per Cent of Acetylene, 37.5 Per Cent of Oxygen and 37.5 Per Cent of Nitrogen

In the View at the Left the Initial Temperature Was 25 Deg. Cent. (77 Deg. Fahr.) and the Pressure 15 Lb. Absolute. In the Other View the Initial Temperature Was 125 Deg. Cent. (257 Deg. Fahr.) and the Pressure Was 25 Lb. Absolute

Fig. 16—Results Obtained with a Mixture of 27.50 Per Cent of Acetylene, 41.25 Per Cent of Oxygen and 31.25 Per Cent of Nitrogen

In the View at the Left the Initial Temperature Was 25 Deg. Cent. (77 Deg. Fahr.) and the Pressure 15 Lb. Absolute. In the Other View the Initial Temperature Was 125 Deg. Cent. (257 Deg. Fahr.) and the Pressure Was 25 Lb. Absolute

Fig. 17—Results Obtained with a Mixture of 30 Per Cent of Acetylene, 45 Per Cent of Oxygen and 25 Per Cent of Nitrogen

In the View at the Left the Initial Temperature Was 25 Deg. Cent. (77 Deg. Fahr.) and the Pressure 15 Lb. Absolute. In the Other View the Initial Temperature Was 125 Deg. Cent. (257 Deg. Fahr.) and the Pressure Was 25 Lb. Absolute

Commenting on the results with carbon bisulphide, Dixon says,

> The flame took an appreciable time to spread through the space occupied by the gas, and in no instance did the

[17]See *Journal of the Chemical Society* (England), vol. 99, p. 588 and vol. 105, p. 2027.

TABLE 4—BEHAVIOR OF MIXTURES OF CARBON BISULPHIDE AND OXYGEN IN THE PROPORTION OF 1 TO 5 AT HIGH COMPRESSION IN A TUBE 12 MM. (0.048 IN.) IN DIAMETER AND 650 MM. (25.59 IN.) LONG

Compression Ratio	Calculated Pressure, Atmospheres	Calculated Temperature		Nature of Flame Movement
		Deg. Cent.	Deg. Fahr.	
1 to 7.3	15.30	335	635	Autoignition near end of tube, no detonation.
1 to 9.4	21.55	394	723	Autoignition near end of tube, no detonation.
1 to 10.5	25.06	422	792	Autoignition near end of tube, no detonation.
1 to 10.5[18]	25.06	422	792	Velocity of 14 meters per sec. (16.40 ft. per sec.)
1 to 10.5[19]	25.06	422	792	Velocity of 60 meters per sec. (196.85 ft. per sec.)

[18]Slow compression.
[19]Fast compression.

flame travel through the tube with a velocity approaching that of detonation. In the fastest instance observed, the flame traveled 25 mm. (0.984 in.) in 0.00025 sec., that is, at 100 meters per sec. (328.08 ft. per sec.), whereas the explosion wave (detonation) travels in this mixture at a rate of nearly 1800 meters per sec. (1.12 miles per sec.).

Further results from the same work of Dixon on mixtures of hydrogen and oxygen, indicated that autoignition took place and that detonation may have developed later in some cases. Results obtained with a mixture of hydrogen and oxygen in the proportion of 1 to 3 are given in Table 5.

In commenting on results obtained with hydrogen-oxygen mixtures in the proportion of 2 to 1 a mixture having a very high detonation velocity of 2800 meters per sec. (1.74 miles per sec.), Dixon says

> When electrolytic gas was fired by compression the spread of the flame was far more rapid than that with excess oxygen; but in no case was the gas detonated instantaneously, even when the fall of the pendulum was unchecked except by the explosion itself.

In these experiments the flame was moving through a gas which was not only at a high density but also at a high temperature, in the one case, approximately 975 deg. cent. (1787 deg. fahr.). In spite of these very high temperatures, the dilute mixtures of carbon bisulphide and oxygen and of hydrogen and oxygen showed low rates of flame movement as compared with what one would expect under these conditions.

It would be expected that when a gas is compressed to a temperature far above its ignition point, every particle of the inflammable gas would essentially either be oxidized or decomposed instantaneously. Dixon has shown, however, that this is not necessarily the case, but that the ignition starts at a point and proceeds slowly with a gradual acceleration, the actual velocity attained depending to a large extent on the point at which ignition started. For example, in his experiments the maximum velocities attained appear to be comparatively low when the autoignition started near the center of the tube, whereas relatively high velocities were attained when the autoignition started near one end of the tube and had the full length of the tube to travel.

The above results from Dixon's early work are, of course, on gases whose behavior may not be representative of that of the fuels used in internal-combustion engines. In Dixon's abstract of results recently presented in England which appeared in THE JOURNAL for December, 1920, he discloses that he has been studying the behavior under compression of such fuels as pentane, hexane, benzine, alcohol and ether. The details of these results are awaited with keen interest.

As stated above, in our work on the influence of increased temperature and pressure on the nature of flame propagation a study was made of a badly knocking fuel, namely ether. Mixtures containing approximately from 6 to 8 per cent of ether were ignited at 150 to 160 deg. cent. (302 to 320 deg. fahr.) initial temperature and pressures of from 65 to 75 lb. absolute. Fig. 18 is a typical example of the characteristic flame record obtained. It may be seen that the flame progressed from ignition at a slowly accelerated rate, until it was arrested a short distance beyond the center of the cylinder. At the time of the arrest autoignition appeared in the unburned gas at a point about equidistant between the advancing flame front and the top of the bomb. Flame spread from this center of autoignition toward both the top of the bomb and the original flame front, causing in

TABLE 5—BEHAVIOR OF A MIXTURE OF HYDROGEN AND OXYGEN IN THE PROPORTION OF 1 TO 3 AT HIGH COMPRESSION

Compression Ratio	Length of Column of Gas at Moment of Firing		Calculated Pressure, Atmospheres	Calculated Temperature		Behavior of Gas
	Cm.	In.		Deg. Cent.	Deg. Fahr.	
1 to 15.0	3.6	1.42	44.3	550 to 578	1022 to 1072	Autoignition near middle of tube. Detonation may have developed.
1 to 18.0	3.0	1.18	57.2	640	1184	Autoignition near end of tube. Burned slowly.
1 to 27.0	2.0	0.79	100.9	810	1490	Autoignition near end of tube. Burned slowly.
1 to 41.5	1.3	0.51	184.5	975	1787	Autoignition near end of tube. Detonation may have developed.

the latter case a decided recession of the original flame front. In some cases, after total inflammation had been accomplished, vibrating compression waves were set up

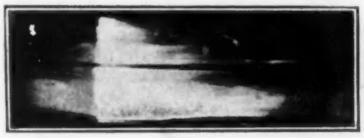


FIG. 18—A TYPICAL EXAMPLE OF FLAME MOVEMENT IN A MIXTURE CONSISTING OF APPROXIMATELY 8 PER CENT OF SULPHURIC ETHER AND 92 PER CENT OF AIR HAVING AN INITIAL TEMPERATURE OF 160 DEG. CENT. (320 DEG. FAHR.) AND A PRESSURE OF 65 LB. ABSOLUTE

in the burned gases similar to those described earlier in this paper.

The most important part of our work with ether-air mixtures was the recording of the pressure development during explosions in which the phenomenon of autoignition took place. Fig. 19 gives the flame and pressure records of an explosion of an ether-air mixture at 150 deg. cent. (302 deg. fahr.) and 65 lb. absolute pressure. In this explosion autoignition appeared but no vibrations occurred in the after-burning. It may be noted that the development of pressure was slow until autoignition appeared. Then the pressure increased with great rapidity.

Fig. 20 gives the records of an ether-air mixture at 150 deg. cent. (302 deg. fahr.) and 75 lb. absolute pressure. Here again autoignition of the high-density gas ahead of the flame front was evident and in this case distinct vibrations were recorded. The records of this explosion are more clearly shown in Fig. 21, in which the flame and pressure curves have been plotted to the

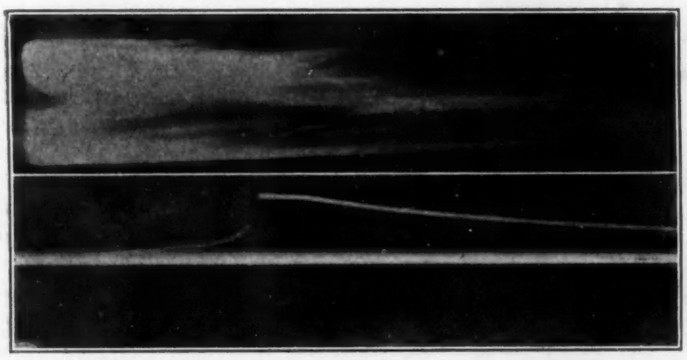


FIG. 19—THE FLAME (UPPER) AND THE PRESSURE (LOWER) RECORD OF AN EXPLOSION OF AN ETHER-AIR MIXTURE AT A TEMPERATURE OF 150 DEG. CENT. (302 DEG. FAHR.) AND A PRESSURE OF 65 LB. ABSOLUTE

same time scale. From this it can be seen that the first appearance of pressure occurred after the flame had traveled approximately one-third of the distance to the top of the cylinder, and that the pressure was thereafter developed slowly until the time at which autoignition occurred. In fact the flame had traveled nearly two-thirds the length of the bomb and a pressure of only 115 lb. per sq. in. had been developed in 0.036 sec. With the appearance of autoignition in the high-density gas pressure developed very rapidly, 425 lb. per sq. in. being recorded in 0.006 sec. The instant of maximum pressure was found to coincide with the instant of total inflammation of the bomb. Upon the attainment of maximum pressure rapid vibrations of the Midgley pressure indicator were recorded. The period of these vibrations has been carefully determined and found to agree exactly with that of the vibrating compression waves in the after-burning as recorded in the flame photograph. In our opinion the pressure record obtained in this explosion appears similar to that shown by the Midgley indicator while ether is knocking in an engine.

THE NATURE OF THE FUEL KNOCK

Of the many theories which have been presented on the nature of the "fuel knock," that of the detonation of the fuel-air mixture in the engine cylinder has recently received considerable credence, and it is certain that if detonation can be set up in the combustion-chamber of an

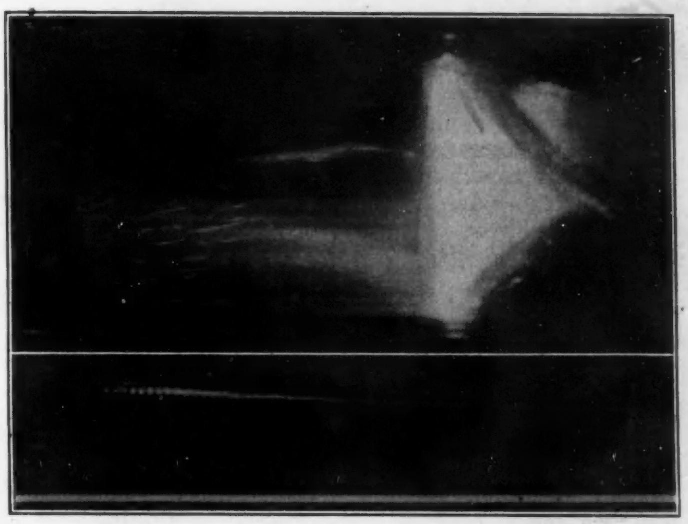


FIG. 20—THE FLAME (UPPER) AND THE PRESSURE (LOWER) RECORD OF AN EXPLOSION OF AN ETHER-AIR MIXTURE AT A TEMPERATURE OF 150 DEG. CENT. (302 DEG. FAHR.) AND A PRESSURE OF 75 LB. ABSOLUTE

engine the phenomenon of knocking would be satisfactorily explained. However, it has been our experience to date that detonation is set up only with great difficulty in a closed cylinder of small dimensions.

On the other hand, autoignition of the high-density gases ahead of the flame front occurs over a wide range of fuel mixtures and conditions and gives a sudden development of pressure similar, in our opinion, to that characteristic of a knocking explosion. It is possible that this autoignition may set up detonation in some cases, thereby acting as an intermediate stage in knocking. Our experiments have not been carried to a definite conclusion, and present data do not warrant presentation of autoignition as a positive explanation for knocking. It is our feeling, however, that information at hand favors more strongly the theory of autoignition of the

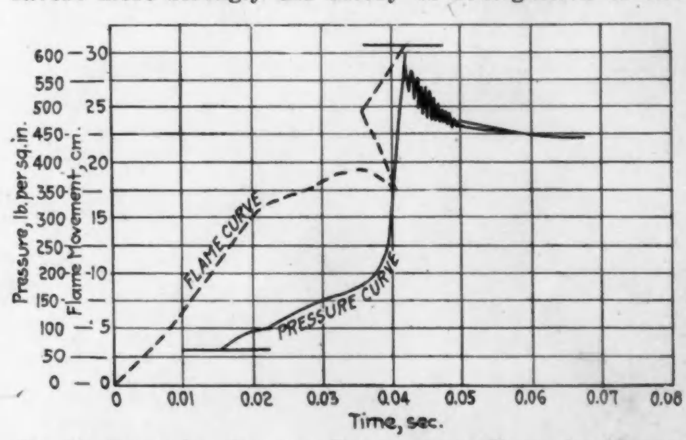


FIG. 21—FLAME AND PRESSURE RECORD OF THE ETHER-AIR MIXTURE AT A TEMPERATURE OF 150 DEG. CENT. (302 DEG. FAHR.) AND AN ABSOLUTE PRESSURE OF 75 LB.

high-density gases ahead of the flame front than that of detonation.

The following four characteristics of the fuel knock have been generally recognized: (*a*) high initial temperature and (*b*) high initial pressure favor knocking; (*c*) the tendency to knock increases with decrease in volatility in comparing the members of the same homologous series and (*d*) volatility and knocking have no relation when different homologous series are compared.

Autoignition of the gas ahead of the flame front is likewise favored by a high initial temperature or pressure of the gas charge. The only results available on the effect of increased temperature on the tendency to detonate, indicate that high temperature inhibits detonation. Moore[20] shows that in the same homologous series the autoignition point becomes lower as the boiling point rises. With decrease in volatility of the members of a series their tendency to autoignite and knock are increased. There are no data at hand to show the relation of the tendency to detonate with the volatility of a given series of compounds.

The many determinations of autoignition points reported in the literature on the subject show conclusively that no relation exists between the volatility and the autoignition point when the comparison is extended to various series of compounds. The information on the tendency of liquid fuels to detonate is meagre. As stated above, Dixon classes ether and alcohol together in their tendency to detonate, and states that pentane and benzine do not accelerate to detonation at atmospheric temperature and pressure. Our attempts to obtain detonation with ether at high temperature and pressure in a 12-in. cylinder were failures. These results are not consistent with the order of the fuels to knock[21]; the tendency being, respectively, ether, pentane, benzine and alcohol.

It should be emphasized also that there is a certain necessary distance of flame travel from ignition to the point at which detonation is set up, and that the distance is increased by the presence of dilutent gases, even excess oxygen. In the engine the explosion chamber is of very small dimensions and the atmosphere is air diluted with from 10 to 25 per cent of the products of combustion. The possibility of detonation under such conditions appears exceedingly remote.

SUMMARY

(1) Apparatus and methods of study have been developed with which the rate and nature of the flame movement and pressure development in gaseous explosions can be recorded under conditions approximating those of the internal combustion engine

(2) It has been shown that in the case of acetylene-air mixtures ignited at atmospheric temperature and pressure the maximum velocity of flame movement is obtained with that mixture corresponding closely to the theoretical proportion for the formation of carbon monoxide

(3) It has been substantiated that first record of pressure development occurs after an appreciable distance of flame travel, and that the instant of maximum pressure development coincides with that of total inflammation of the gas charge

(4) A theory has been presented that the arrest occurring in mixtures fired without turbulence, and the consequent vibrations noted in the burning gases, are due essentially to the high density developed in the gases ahead of the flame front

(5) It has been confirmed that turbulence greatly accelerates flame propagation, and it has been shown that turbulence changes the character of the flame travel by the elimination of the sudden arrest and vibratory movement

(6) Within the limits of the experiments carried out it was found that increased temperature and pressure have little effect upon the rate of flame propagation

(7) The initiation of a detonation has been found possible at atmospheric conditions and in a closed cylinder of 12-in. length only by the use of relatively high concentrations of acetylene and a thorough enrichment of the atmosphere with oxygen

(8) Preliminary results have been presented which indicate that high temperature inhibits the initiation of the detonation

(9) It has been shown that autoignition of the high-density gases ahead of the flame front occurs over a wide range of mixtures and conditions and that it is especially favored by high temperature and pressure

(10) A record of pressure development in an explosion of an ether-air mixture in which autoignition occurred in the high-density gases ahead of the flame has been obtained; this record, in our opinion, is similar to that of a knocking explosion of ether

(11) A theory has been advanced that autoignition of the high-density gases ahead of the flame front is accountable for the fuel knock

[20]See *Journal of the Society of Chemical Industry*, vol. 36, p. 109.
[21]See THE JOURNAL, August, 1920, p. 123.

Standardization of Petroleum Specifications

THE Government Committee on Standardization of Petroleum Specifications has recently issued a bulletin[1] setting forth the specifications which must be met by all petroleum products sold to Government agencies after Dec. 29, 1920. The Committee on Standardization of Petroleum Specifications, created by an order of the President issued July 31, 1918, is charged with the "duty of preparing and adopting specifications for the supply of petroleum and its products to any and all departments, bureaus, agencies and offices of the Government" under the direction of the United States Fuel Administrator.

Certain of the specifications drafted by the Committee are universally applied by petroleum refiners in the production of gasoline and lubricants sold to the owners of automotive apparatus. The Committee appreciating this fact consults with representatives of the automotive and petroleum industries when revisions and additions are made and this practice insures the drafting of specifications which are generally acceptable to private consumers as well as the Government. On Dec. 23, some of the technical advisers to the Committee met with the Lubricants Division of the Standards Committee and discussed the present specifications as they had drafted them for use in 1921. The discussion brought out the fact that the Government Committee was anxious to cooperate with the industry and suggested that the specifications affecting automotive apparatus be widely circulated and constructive criticism submitted to the Committee for its consideration. For this reason an abstract of the recent bulletin is published herewith for the information of our members.

Methods of Testing

The bulletin describes in considerable detail the prescribed methods of conducting the tests which must be made under the specifications. These will not be reprinted here because of their comprehensive character. The report itself should be consulted by those particularly interested in the testing methods and apparatus. In general, the Committee has adopted the methods recommended by the American Society for Testing Materials, as these methods agree with those used by Government agencies and also have the sanction of a number of petroleum trade associations.

Methods of applying the "doctor" test to gasoline are given as well as the procedure and apparatus for determining the distillation characteristics of a particular sample. Methods for checking the flash and fire points of lubricating oils are described in detail with the prescribed methods of measuring viscosity. The pour test, tests for carbon residue and acidity, method of determining emulsification and demulsibility are all fully outlined so that the application of the specifications will be uniform and all results comparative.

The Committee recognizes the fact that the tests specified for lubricating oils may not necessarily determine their effectiveness as lubricants but it is felt that the practical application of the specifications as drawn will at least prevent the purchase of the poorer oils and offer an opportunity to study further the properties of oils which guarantee efficient lubrication.

Gasoline and Kerosene

Three grades of gasoline are covered by the specifications; motor gasoline, for use as a fuel in automobile, motorboat and similar engines; aviation gasoline, fighting grade, for use as a fuel in engines of fighting planes where the highest efficiency is required; and aviation gasoline, domestic grade, for aviation engine fuel where the fighting grade is not required. For convenience in making comparisons these three specifications are given in Table 1.

TABLE 1—COMPARATIVE CHART OF GASOLINE SPECIFICATIONS

Grade[2]	Commercial Gasoline	Aviation Gasoline, Domestic Grade	Aviation Gasoline, Fighting Grade
Color	White	Water White	Water White[3]
Doctor Test shall be negative	Not specified	Applies	Applies
Corrosion Test; 100 cc. of the gasoline shall cause no gray or black corrosion and no weighable amount of deposit when evaporated in a polished copper dish	Not specified	Applies	Applies
Unsaturated Hydrocarbons; maximum proportion of the gasoline soluble in concentrated sulphuric acid, per cent	Not specified	2	1
Acid Heat Test; The gasoline shall not increase in temperature more than 10 deg. fahr	Not specified	Applies	Applies
Thermometer reading when first drop is recovered in receiver not more than	140 deg. fahr.		
Thermometer reading range when 5 per cent is recovered in receiver		122 to 167 deg. fahr.	122 to 149 deg. fahr.
Thermometer reading when 20 per cent is recovered in receiver not more than	221 deg. fahr.		
Thermometer reading when 50 per cent is recovered in receiver not more than	284 deg. fahr.	221 deg. fahr.	203 deg. fahr.
Thermometer reading when 90 per cent is recovered in receiver not more than	374 deg. fahr.	311 deg. fahr.	257 deg. fahr.
Thermometer reading when 96 per cent is recovered in receiver not more than		347 deg. fahr.	302 deg. fahr.
End-point shall not be higher than	437 deg. fahr.	374 deg. fahr.	329 deg. fahr.
Distillate recovered in the receiver from the distillation at least	95 per cent	96 per cent	96 per cent
When the residue is cooled and added to the distillate in the receiver the distillation loss shall not exceed		2 per cent	2 per cent
Acidity: The residue after distillation shall not show an acid reaction		Applies	Applies

[2]Each grade of gasoline shall be free from undissolved water and suspended matter.
[3]The War Department requires the fighting grade to be colored red after inspection and acceptance.

Two grades of kerosene are covered, one for illuminating purposes, the other as a fuel. The specification for fuel kerosene follows:

PRIME WHITE KEROSENE

This specification covers the grade of kerosene used where kerosene is required primarily as a fuel and for cleaning purposes. This oil can be used as an illuminant in case of necessity.

The oil shall be free from water, glue, and suspended matter.

Color: The color shall not be darker than No. 16 Saybolt.

Flash point: The flash point shall not be lower than 115 deg. fahr. (Tag closed tester)

Sulphur: The sulphur shall not be more than 0.09 per cent.

Floc: The floc test shall be negative.

Distillation: The end point shall not be higher than 625 deg. fahr.

Cloud test: The oil shall not show a cloud at 5 deg. fahr.

Burning test: The oil shall burn freely and steadily for 8 hr.

[1]Report of Committee on Standardization of Petroleum Specifications printed in Bulletin No. 5 of the Bureau of Mines. Copies of the bulletin can be secured without charge by addressing the Director, Bureau of Mines, Washington.

Fuel Oil for Diesel Engines

Fuel oil intended for use in Diesel engines must pass the following specification.

This specification covers the grade of oil used as a fuel for Diesel engines.

Fuel oil shall be a hydrocarbon oil, free from grit, acid and fibrous or other foreign matters likely to clog or injure the burners or valves. If required, it shall be strained by being drawn through filters of wire gauze of 16 meshes to the inch. The clearance through the strainer shall be at least twice the area of the suction pipe, and the strainers shall be in duplicate.

Flash point: The flash point shall not be lower than 150 deg. fahr. (Pennsky-Martens closed tester)

Water and sediment: Water and sediment combined shall not amount to more than 0.1 per cent.

Carbon residue: The carbon residue shall not exceed 0.5 per cent.

Precipitation test: When 5 cc. of the oil is mixed with 95 cc. of petroleum ether and allowed to stand 24 hr., it shall not show a precipitate or sediment of more than 0.25 cc. or 5 per cent by volume of the original oil.

Lubricating Oils

Oils for general lubrication purposes are divided into three classes by the Committee and a set of specifications has been drafted for each class. The service for which each oil is intended is as follows:

Class A: This specification covers the grades of petroleum oil used for the general lubrication of engines and machinery where a highly refined oil is not required. This oil is not to be used for steam cylinder lubrication.

Class B: This specification covers the grades of petroleum oil used for the lubrication of turbines, dynamos, high-speed engines and other classes of machinery where an oil better than Class A is required. The oil shall be satisfactory for use in circulating and forced feed systems.

Class C: This specification covers the grades of petroleum oil used by the United States Government and its agencies for lubrication of air compressors and internal-combustion engines, except aircraft, motorcycle and Diesel engines; also for the lubrication of turbines and other machinery where an oil better than Class B is required. This oil shall be satisfactory for use in circulating and forced feed systems.

Table 2 is arranged so that the points on which the specifications for the three oils differ can be readily compared. The paragraphs applying to all classes alike are listed under the table.

TABLE 2—COMPARATIVE CHART OF LUBRICATING OILS

	Class A	Class B	Class C
Acidity: The weight of potassium hydroxide required to neutralise 1 gram of oil shall not exceed	0.10 mg.	0.07 mg.	0.05 mg.
Emulsifying Properties: The oil shall separate[4] in 30 min. from an emulsion with (1) Distilled water (2) 1 per cent salt solution (3) Normal caustic soda solution. The demulsibility shall not be less than 300	Test not required	Test applies	Test applies
Carbon Residue: The carbon residue shall not exceed the following	Test not required	Test not required	per cent Extra Light 0.10 Light 0.20 Medium 0.30 Heavy 0.40 Extra Heavy 0.60

[4]This means that there shall be only a slight cuff between the water and the oil.

Only refined petroleum oils without the admixture of fatty oils, resins, soap, or other compounds not derived from crude petroleum, will be considered.

These oils shall be supplied in five grades, known as extra light, light, medium, heavy and extra heavy.

Flash and Fire Points: The flash and fire points of the five grades shall not be lower than the following:

Grade	Flash deg. fahr.	Fire deg. fahr.
Extra Light	315	355
Light	325	365
Medium	335	380
Heavy	345	390
Extra Heavy	355	400

Viscosity: The viscosity of the five grades of oil at 100 deg. fahr. shall be within the following limits:

Grade	Sec.
Extra Light	140-160
Light	175-210
Medium	275-310
Heavy	370-410
Extra Heavy	470-520

Color: The color of the extra heavy grade shall not be darker than No. 6 National Petroleum Association Standard, or its equivalent. The color of the other grades shall not be darker than No. 5 National Petroleum Association Standard, or its equivalent.

Pour Test: The pour test shall not be above the following temperatures:

Grade	Deg. fahr.
Extra Light	35
Light	35
Medium	40
Heavy	45
Extra Heavy	50

Corrosion: A clean copper plate shall not be discolored when submerged in the oil for 24 hr. at room temperature.

Further tests on oils of Class C may be required at the option of the Department of the Government using the oils.

Aviation Engine Lubricating Oil

Lubricating oils for use in aviation engines are covered by an individual specification separate from the group of oils for general lubrication purposes. A difference of opinion exists between the War and Navy Departments regarding the characteristics of a suitable oil for aviation engines and this has necessitated the inclusion of two distinct grades in the specification. They differ principally in viscosity, the Navy preferring the lighter oil, grade 1. Oil for lubricating motorcycle engines is purchased under this same specification which follows.

LIBERTY AERO AND MOTORCYCLE OIL

This specification covers the grades of oil used for the lubrication of stationary cylinder aircraft engines and motorcyles.

The oil shall be made from pure, highly refined petroleum products and must be suitable in every way for the entire lubrication of stationary cylinder aircraft engines and motorcycle engines operating under all conditions. The oil shall not contain moisture, sulphonates, soap, resin or tarry constituents which would indicate adulteration or lack of proper refining.

These oils shall be supplied in two grades, to be known as Grade 1 and Grade 2.

Flash Point: The flash point of the two grades shall not be lower than 400 deg. fahr. for Grade 1 and 500 deg. fahr. for Grade 2.

Viscosity: The viscosity of the two grades at 210 deg. fahr. shall be within the following limits:

Grade 1 (Summer)	90-100 sec.
Grade 1 (Winter)	75- 85 sec.
Grade 2	125-135 sec.

Pour Test: The pour test of Grade 1 shall not be above the following limits:

Summer 45 deg. fahr.
Winter 15 deg. fahr.

Cold Test: The cold test of Grade 2 shall not be above 35 deg. fahr.

Acidity: Not more than 0.10 mg. of potassium hydroxide shall be required to neutralize one gram of Grade 1 oil.

Emulsifying Properties: The oil shall separate completely in 1 hr. from an emulsion with distilled water at a temperature of 180 deg. fahr.

Carbon Residue: The carbon residue on Grade 1 shall not be over 1.5 per cent; on Grade 2, not over 2.0 per cent.

Precipitation Test: When 5 cc. of the oil is mixed with 95 cc. of petroleum ether, and allowed to stand 24 hr., it shall not show a precipitate or sediment of more than 0.25 cc. (5 per cent by volume of the original oil).

Transmission Lubricant and Cup Grease

The following specifications regulate the quality of oils purchased for use in transmissions and axles.

TRANSMISSION LUBRICANT

This specification covers the grade of petroleum oil used for the lubrication of transmission gears and bearings, differential gears, worm drives, winch drives, and roller and ball bearings used in connection with such parts of the equipment of motor vehicles.

The lubricant shall be a refined petroleum product, without the addition of any vegetable or animal oils or products derived from them, and be entirely free from fillers.

Flash Point: The flash point shall not be lower than 460 deg. fahr.

Viscosity: The viscosity at 210 deg. fahr. shall be within the following limits:

175 to 220 sec.

CUP GREASE

This specification covers the grades of cup grease used for the lubrication of such parts of motor equipment and other machinery as are lubricated by compression cups; Nos. ½ and 1 to be used in spindle cups or transmissions.

The grease shall be a well manufactured product, composed of a calcium soap made from high grade animal or vegetable oils or fatty acids, and a highly refined mineral oil.

The mineral oil used in reducing the soaps shall be a straight well refined mineral oil with a viscosity at 100 deg. fahr. of not less than 100 sec.

Soap Content: No. ½ cup grease shall contain approximately 13 per cent of calcium soap. No. 1 cup grease shall contain approximately 14 per cent of calcium soap. No. 3 cup grease shall contain approximately 18 per cent of calcium soap. No. 5 cup grease shall contain approximately 24 per cent of calcium soap.

Consistency: These greases shall be similar in consistency to the approved trade standards for Nos. ½, 1, 3 and 5 grease.

Moisture: The grease shall be a boiled grease, containing not less than 1 or more than 3 per cent of water when finished.

Corrosion: A clean copper plate shall not be discolored when submerged in the grease for 24 hr. at room temperature.

Ash: The ash shall not be greater than 1.7 per cent for No. ½ grease. The ash shall not be greater than 1.8 per cent for No. 1 grease. The ash shall not be greater than 2.3 per cent for No. 3 grease. The ash shall not be greater than 3.5 per cent for No. 5 grease.

Fillers: The grease shall contain no fillers such as resin, resinous oils, soapstone, wax, talc, powdered mica or graphite, sulphur, clay, asbestos, or any other filler.

Criticisms and Suggestions

The members of the Society are requested to study the specifications carefully in relation to their experience submitting their comments to the Chairman of the Committee on Standardization of Petroleum Specifications, M. L. Requa, Bureau of Mines, Washington. Copies of the specifications can be secured without charge upon application to the Director, Bureau of Mines, Washington, for Bulletin No. 5.

AMERICAN AERONAUTIC PILOTS

THE recent Pulitzer Trophy Race was further evidence that American pilots are as good as any in the world. Foreign authorities have laid great stress on the exploits of their pilots and some people in this country have received the impression that the United States is outclassed in that respect. It is an absolute fallacy. One of the principal reasons for the lack of mention of individual pilots has been the large number of first-class pilots at work in this country. The unfortunate dearth of aviation meets has allowed the daily papers to forget to some extent the existence of these men.

The aerial mail is an example of the public's forgetfulness of the excellence of the pilots employed. It is one thing to fly from one airport to another on a clear warm day, but it is a different proposition to take-off in a fog and fly through a snowstorm or two with the temperature below zero. That is what the mail pilots are required to do very frequently. Flying on schedule in storms requires a much higher order of piloting than incidental flying in the neighborhood of an airport. Many of the pilots in the mail service have had over 2000 hr. of flying. That figure may not seem much to the layman, but it requires steady flying for a few years to obtain it, or to put it another way, about 150,000 miles of travel.

The Army and the Navy have many pilots who can be classed among the best in the world. The race brought several of them into prominence and there are many more yet to be heard from. The Mineola-Alaska flight was as big a feat as the Cairo-to-the-Cape flight. It was much more of a success. There were no casualties and the same machines returned without major repairs. In the other famous flights that have been made since the war there is no instance of more than one machine completing its mission. Such public meets as the Pulitzer race allow the service pilots a chance for recognition. It is a maxim of military and naval affairs that good work is the duty of an officer and that publicity cannot be permitted. This is essential to discipline and coordination of effort. But in open competition with civilians in a sporting event or in performing some extremely hazardous enterprise such as crossing the Atlantic or flying to Alaska, it is due to the officer and his country that the facts be known. The public should not, because it does not know the names of the fine pilots we have, believe that they do not exist.—*Aviation.*

The Alaskan Flying Expedition

By First-Lieut. St. Clair Streett[1], U. S. A.

Washington Section Address *Illustrated with* Drawing and Photographs

DURING the latter part of December, 1919, the idea of an airplane flight to Alaska was conceived in the office of the Chief of Air Service. The advantages of such a flight were immediately evident, but it was not decided what type of equipment could be used; any plane decided upon would be called upon to exhibit a varied number of abilities. In February, 1920, instruction was given to prepare the proposal of this contemplated flight to Alaska for authorization by higher authority. Before this could be done, it was necessary to secure the consent and cooperation of the Canadian government to allow the flight over Canadian territory, and further to allow the shipment of the necessary supplies to points within the Canadian border.

In laying out the route, care was taken to have this along lines of communications, as well as by the shortest way possible. Every available source of information concerning British Columbia, Yukon Territory and Alaska was consulted; individuals who were conversant with the country were interviewed whenever possible to obtain a more human idea of the territory over which the flight was contemplated. When the route was finally decided upon, it was seen that more than half the distance to be covered lay over a most mountainous and sparsely settled country, all the maps of which we were able to obtain were incomplete and inaccurate.

On May 1, 1920, the final approval of the project was given by the War Department, and active plans for the flight were inaugurated. It was planned to have equipment and personnel ready to start by June 15, 1920. The undertaking of allocating in the short time available the material and supplies, as well as gasoline and oil, to such remote places as White Horse and Dawson in the Yukon, and Fairbanks and Ruby in Alaska, was indeed appalling. The approval of the flight contained authorization to send an officer ahead of the expedition to visit all the points at which planes were to stop, to arrange for proper landing fields, proper custody of supplies, and to obtain information for use on the flight. The start of the flight was postponed until July 15, due to the Reorganization Bill going into effect on July 1.

The DH4B air plane was finally chosen for the equipment, and the officers of the expedition designated as pilots proceeded with their mechanics to the factory where new planes of this type were being assembled after being converted from DH4's. These officers and men spent nearly two weeks going over the planes to make them comfortable and to remove all unnecessary weight and paraphernalia.

The Alaska flight, like every other cross-country flight attempted, depended greatly on communication facilities for its success. In this flight it was not possible to use any but the regular commercial means of communication. In flying over such an extended, unknown and in many places unchartered area, advance information on the weather was of especial importance. The Weather Bureau at Washington had agreed to furnish as much information on average conditions as was available, but after leaving the Eastern coast the weather prognostications from Washington were of little value. The local weather bureaus were to furnish forecasts for areas to be traversed. In Alaska itself the Signal Corps was to cooperate in furnishing data on the weather conditions.

Start of the Flight

On July 15, 1920, at Mitchel Field, Long Island, the four planes were ready to leave the ground at 12.15 p. m. The pilots and mechanics of the expedition were given a final address, covering the instructions and policy governing the flight, by Brigadier-General William Mitchell. The flight took off at 12.33 p. m. in formation, circling the field, and took up its course, with compass bearing 298 deg., and all engines apparently running beautifully. Heavy weather was encountered 10 min. out of Mitchel Field in the form of fog and rain. The flight formation was broken up, it being almost impossible to see in the thick weather and possibility of collision being imminent. The cloud bank was approximately 2500 ft. thick. Planes Nos. 2, 3, and 4 went through clouds and flew at approximately 1000-ft. altitude through rain, while No. 1 climbed to an altitude of approximately 8000 ft., above the clouds, and held a compass course for Erie, Pa. At Wilkes-Barre, Pa., hail and rain were encountered in such volume as to force Plane No. 1 down through the clouds to seek a landing which was made in a wheat field about 8 miles east of Wilkes-Barre and an axle was broken in effecting it. Spare parts were sent immediately from Mitchel Field by rail, and the 16th was spent in making the necessary repairs on this plane before take-off could be made. The three other planes of the expedition had landed at Erie after a $5\frac{1}{2}$-hr. flight, during which they encountered rain and fog almost the entire time.

On July 17, plane No. 1 left Elmhurst, Pa., at 8.35 a. m. and landed at Erie at 12.35 p. m., after an uneventful trip, with clear weather all the way, although against a considerable headwind. The country traversed between New York City and Erie has been considered rough by flyers, and is a territory on which natural landing fields are not frequent. The afternoon of the 17th was spent going over all four planes to make ready for the next day's hop to Grand Rapids.

It rained all day on both July 18 and 19. On July 20, after several attempts to take-off from a soft field, Lieutenant Crumrine finally succeeded and escaped serious accident by only a very narrow margin. The field was so soft that it was considered impracticable to tempt fate further by trying to get all four planes off before the field had been rolled. The afternoon of the 20th was spent in running a heavy truck up and down the field to pack the ground. We hired a team of horses to stand by to pull the truck out whenever it became stuck, which it did frequently. Word was received in the afternoon that Lieutenant Crumrine had safely landed at Grand Rapids.

Everyone was on the field early on July 21 and the planes were ready. At 9.00 a. m. Lieutenant Kirkpatrick took-off and barely missed some trees, getting out of the

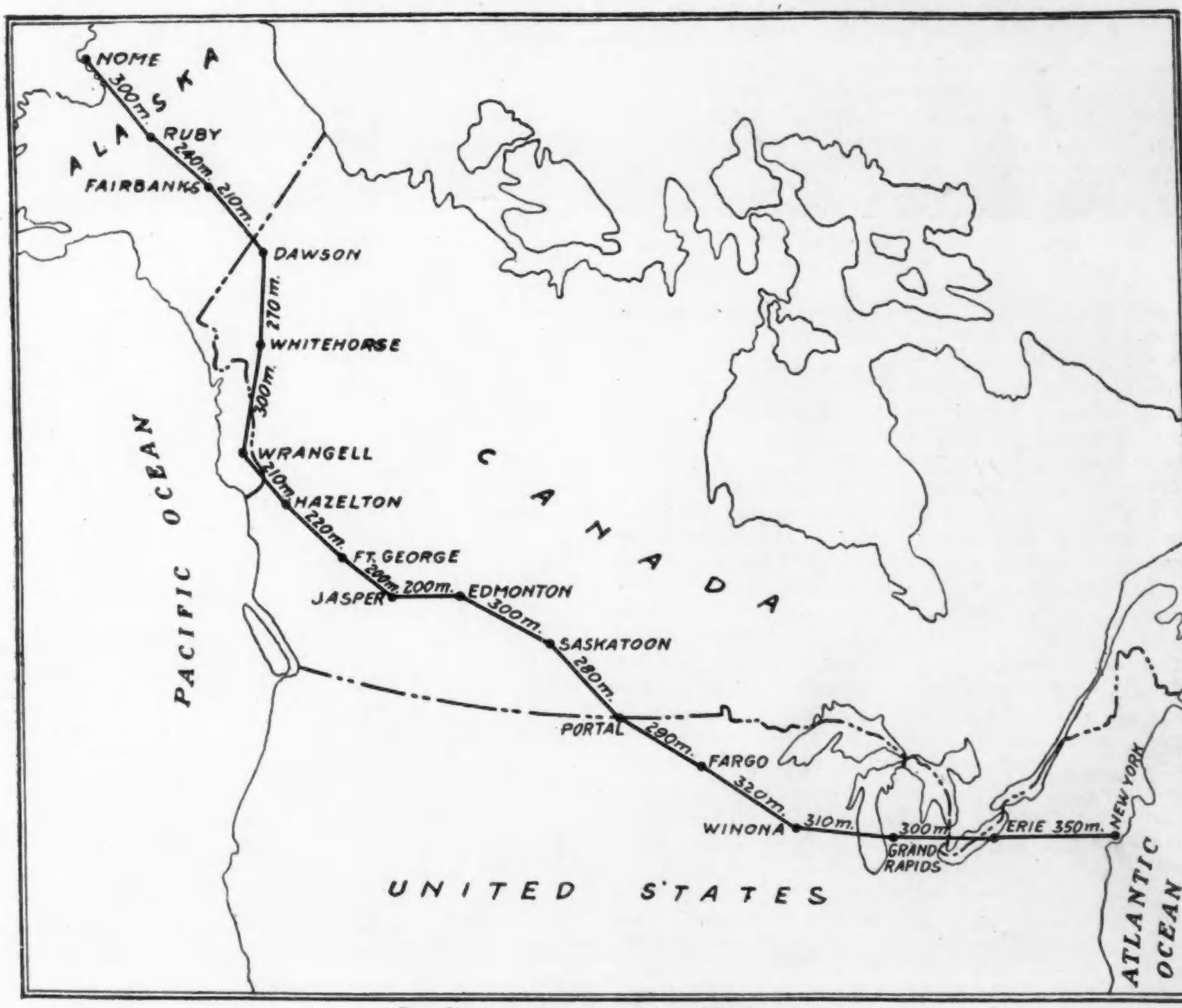
[1]Air Service, Washington. Lieutenant Streett was in command of the Alaskan Flying Expedition which recently completed a successful airplane flight from New York City to Nome, Alaska, and return.

small field. Lieutenant Nutt and I followed him at about 1-min. intervals, and we both experienced sufficiently narrow escapes to thank the good Lord when we were finally in the air and circling over the field, preparing to strike out for Grand Rapids. After gaining sufficient altitude, we picked up the course and started across Lake Erie. After 10 min. the shore line dropped behind us, and at 7000 ft., due to the thick mists that prevailed, was soon entirely lost to sight. After flying for 70 min. entirely by compass without seeing more than one vessel on the lake, you can easily imagine our great joy when we finally descried the Canadian shore. The flight was over the upper end of Lake St. Clair, Selfridge Field and the lake region around Pontiac, Mich., finally ending at the flat region surrounding Grand Rapids. Landing was made at 12.20 p. m. Central Time, after 3 hr. and 20 min. in the air. The crews of the four planes remained on the field until 10.00 p. m., preparing for the next day's flight.

The planes took off at 11.30 a.m. on July 22, at about 30-sec. intervals. The flight formed at about 2000-ft. altitude over the field and we picked up our course 284 deg. to Winona, Minn., which took us directly across Lake Michigan at its widest point, from Grand Haven, Mich., to Port Washington, Wis. At 12.05 p. m. we were over Lake Michigan and had lost sight of the Michigan shore. The visibility was extremely poor. This entire section seemed to be covered by a smoke haze which attained a

THE COUNTRY NEAR WINONA, MINN.

height of 8000 ft., which was, incidentally, the altitude we maintained crossing the lake. It was again necessary to rely entirely upon the compasses for direction, and lonesomeness stimulated our imagination to the extent that the engines made various kinds of sounds, all of which seemed to prophesy engine failure, but when we sighted the Wisconsin shore at about 12.55 p. m., the engines appeared to be running beautifully. The country between Port Washington and Mauston was very marshy in



ROUTE OF THE ALASKAN FLYING EXPEDITION

NEARING THE LANDING FIELD AT SASKATOON, SASKATCHEWAN
There Are Miles and Miles of Uncultivated Land Similar to That Shown

places and would afford few good landing fields, but was indeed wonderful as compared with the monotonous waste of water of Lake Michigan.

The flight landed at Winona, Minn., at 2.45 p. m., after 3¼ hr. in the air. We had received an urgent invitation to stop at Minneapolis on our way to Fargo. This invitation we decided to accept, and preparations for take-off for Minneapolis from Winona were made the same afternoon. At 6.00 p. m. all the planes were again in the air circling over Winona and on the way to Minneapolis. It was one of the most beautiful flights we had experienced, flying up the valley of the Mississippi 100 miles just before sundown. When just east of St. Paul our flight was met by an airplane from the Curtiss Northwestern Aeroplane Co., Minneapolis, which escorted us to the landing field of the Twin City airdrome, where landing was made at 7.25 p. m. We were welcomed by a number of enthusiastic gentlemen, who were intensely interested in the future of aviation, and especially in its progress in the State of Minnesota.

July 23rd was spent in repairing and carefully looking over all machines prior to the flight to Fargo, which was proposed for the 24th. On July 24th our flight took off at 11.47 a. m., and after circling to an altitude of 5000 ft. we headed for Fargo. The atmosphere was so clear that one could see from 40 to 50 miles, and as this section in Minnesota is dotted with innumerable lakes surrounded by wonderful farms, our flight to the edge of the great prairie country was particularly beautiful. The flight to Fargo was made in 2 hr. and 24 min. Arriving at Fargo, we were given a welcome by a number of enthusiastic citizens, who were very much disappointed because we could not leave our planes to accept their kind invitation to lunch until after our engines had been carefully checked and the tanks refilled witn gasoline and oil, which practice had been adopted and carefully carried out from the start.

A start was made for Portal, N. D., at 9.25 a. m. the next day. The engines were running beautifully. After take-off an altitude of approximately 4000 ft. was attained and maintained for the entire distance, 290 miles, to Portal, which was reached in 3 hr. and 10 min.

The territory flown over up to a point 200 miles north and west of Fargo was the flat wheat country for which this section of the United States is noted. Landing could be effected anywhere without danger of accident. From that point on, however, the bad lands of North Dakota were traversed. This country is interspersed with small saline lakes and is used mostly for cattle raising.

FLYING OVER CANADA

At Portal we crossed into Canadian territory for the first time. Our landing field was, in fact, on the Canadian side of the line. Landing was effected by all the planes without damage, and preparation was immediately made for the continued flight to Saskatoon on the 26th. We had begun to be very hopeful at this time with almost half our journey completed, and with weather that prom-

ised to remain favorable until we should reach the mountains of Alberta and British Columbia. Up to this time we had been using a type of oil furnished by the Air Service. Portal was the first stop at which we used Mobiloil B, which incidentally we continued to use from there on.

We left ground for Saskatoon at 10.05 a. m. July 26. The country from Portal to Regina was monotonously flat and almost treeless. North of Regina the terrain surrounding Last Mountain Lake was slightly hilly, and this beautiful body of water, which is not over three-quarters of a mile wide at its widest point, extends north and east from Regina for a distance of about 60 miles. It was while over this territory that we got our first idea of the wide expanse of the comparatively new country just over our border in Alberta and Saskatchewan. Thousands of acres of this land have never been tilled, and ranches and homes are thinly scattered over it.

The run of 290 miles from Portal to Saskatoon was negotiated in 4 hr. 15 min. We arrived at 12.07 p. m., having bucked a 20 m.p.h. wind all the way up.

On July 27 take-off was effected at 9.51 a. m., with the prospect of a beautiful flight with clear weather to Edmonton. The country due west of Saskatoon is spotted with innumerable small lakes and is very thinly settled. Most of the land is covered with a growth of swamp poplar, which is only from 15 to 20 ft. tall and very thick. There are several Indian reservations in this immediate section. Immediately west of this section, from the village of Rosehaven to the edge of Lake Manitou, cleared and tilled fields extend in every direction and landing would be possible at any place if proper care were exercised. We were bucking a headwind of about 20 m.p.h. A peculiar thing about it was that the wind was of apparently constant velocity anywhere from 100 ft. to 7000 ft. altitude.

Edmonton was the last stop where supplies could be obtained and extensive work on airplanes could be done without the necessity of shipping supplies in; so we planned to give the planes a thorough overhaul to insure absolute fitness for the flight into the mountains. Two days were to be spent doing this work, but as two gas tanks had developed leaks, and it was necessary to disassemble almost entirely the planes to get the tanks out for repairs, we stayed at Edmonton a day longer than we had anticipated. On the 29th we left for Jasper, but were forced to return to airdrome at Edmonton after a flight of 1¾ hr., due to the fact that when almost at the mountains the visibility became so poor on account of storms coming down from the north that we were unable to proceed with any assurance of success.

On Aug. 1 at 9.37 a. m., a fresh start was made. We were forced to fly into a headwind of about 15 m.p.h., although the weather was beautifully clear and it was possible to see for many miles, after altitude was reached. Up to the Pembina River west of Edmonton and south of the Grand Trunk Railway, the country is tilled and rather thickly settled, but from that point on the country is

Bad Lands East of the Jasper National Park in Alberta
This Country Is Almost All Swamp and Looks Very Forbidding from an Airplane

View Taken While Going Through the Yellow Head Pass

wilder and rougher. Shortly after crossing the Pembina River we were able to discern at a great distance due west the white-capped peaks of the Rockies. About 15 min. later visibility became very poor, due presumably to smoke from forest fires in the vicinity of Jasper National Park and eastern British Columbia. This condition prevailed until we reached the eastern shore of the Athabasca River, at which point the atmosphere became clear again and we were able to proceed up the Athabasca to Jasper under a clear sky, which gave us a wonderful opportunity to admire the solemn grandeur of the Rocky Mountains which we were paralleling on our right. It seemed impossible that a place could be found large enough to land an airplane in all this great waste of rock and snow, but after flying up the Athabasca for about 15 min. we turned around the shoulder of a mountainous projection into the valley, and a great level flat was exposed along the shore of the Athabasca, upon which we descried the signal smoke and landing cross which indicated our landing field. Landing was made at 11.15 a. m. Pacific Time, after a run of approximately 3 hr.

The Country to the North of Hazelton, B. C.

Sunset on the Arctic Ocean

We landed on a natural flat that had been obstructed by occasional stumps and cleared by Col. Maynard Rogers and his park rangers. This was our first experience of landing in the wilds where airplanes had never been seen and natural obstacles seemed to forbid the use of air-

Typical Country Around Cape Prince of Wales

craft. Our landing field was situated approximately 15 miles from the town of Jasper.

On the morning of Aug. 2 we prepared for an early departure. Leaving the ground at 8.30, we flew up the valley of the Athabasca River to the valley of the Miette, through which the railroad runs to Yellow Head Pass. In passing over the town of Jasper Plane No. 1 caught fire, due to the spraying of oil from reserve tanks over hot exhaust-pipes. This plane side-slipped to about 200 ft. over the Athabasca River and, accompanied by the three other planes, succeeded in getting back to landing field. After the safety of Plane No. 1 was assured, the remaining three planes of the flight, which were still in the air, resumed their journey to Fort George.

Bad Weather Encountered

After removing obstructions in the oil-tanks, Plane No. 1 was again ready to fly. Take-off was made about 1.30 p. m., and after circling the field to be sure the engine was running properly, we headed over the slope of Pyramid Mountain for Yellow Head Pass. At the time of our take-off snowstorms were prevailing upon the highest peaks bordering the pass, while considerable rain could be seen at intervals in the pass itself. As we proceeded up Miette Valley we began to encounter thick smoke, caused by forest fires on both sides of Yellow Head Pass. Seven distinct fires were counted from about 3000 ft. over the town of Pocahontas, which is very near the summit. The smoke, in conjunction with occasional rain and hailstorms encountered, made the trip to the

The Taku Glacier

pass an extremely uncomfortable one, and when once through we congratulated ourselves heartily. Before us in a straight line projected the valley of the Frazer River, which runs between the Rocky Mountains and the Caribou Range to the south. The slopes of the mountains in this area are completely covered with a heavy growth of fir, hemlock and spruce; the smell of evergreen was discernible even at an altitude of 8000 ft. The Grand Trunk

Looking Down on the Yukon River and the Swamps Which Extend for Miles in the Low Country on Both Sides of the River

Pacific Railroad parallels the Frazer River nearly to Fort George, so that there was no difficulty in determining our exact location from time to time. After flying for ½ hr. down Frazer Valley, we began to encounter a strong headwind, which seemed of unvarying velocity between the altitudes of 1500 and 9000 ft. There was not much to choose in the matter of altitudes, it being impossible to land with safety within a radius of 50 miles.

At Hansard, we began to run into severe rainstorms from the southwest. The wind began to increase until a velocity of about 50 m.p.h. was reached. From Hansard to Fort George, a distance of approximately 35 miles, we were flying through continual storms and most of the time not over 200 ft. above the tree-tops. You can easily imagine our intense joy when Fort George was finally sighted through rain, which made it almost impossible to see even objects immediately below us. Landing was made at 5.30 p. m., after a 4-hr. run. In landing, due to poor visibility, we were unable to see objects directly ahead on the field, with the result that the left lower wing of one plane was damaged seriously by contact with stumps and trees. The other planes had landed without mishap earlier in the day.

Eleven days were spent at Fort George repairing the wing of the damaged plane and arranging for the cutting of grain on and leveling the field which was to be used for landing at Hazelton. On Friday, Aug. 13, all was made ready for the start to Hazelton. Superstition was thrown to the winds and, to prove that we were flying in the face of fate, we gave our mascot away. With all these odds against us we took-off at 8.55 a.m., and after a very beautiful trip unmarred by any unpleasant incident and over a very rough and rugged country, we arrived at Hazelton, the northernmost point touched by a railroad in North America. Landing was made at 12.20 p.m. At Hazelton the majority of the inhabitants had never before seen an airplane, and consequently we were a curiosity to them. Around Kispiox, which is just north of Hazelton on the Skeena River, are a number of Indian reservations, and naturally we were visited by a great number of natives from this place, whose curiosity was boundless. The airplane was dubbed by them as the 'steamboat of the air." The people of Hazelton were extremely cordial, and we were banqueted by the veterans of the Great War. On Aug. 14 we spent the entire forenoon rolling the field and preparing our planes for what we considered our hardest jump, that from Hazelton to Wrangell over the Coast Range. This territory over which we were to fly was a stretch about which very little was known, and upon which very little data had been obtained. It was known that a great many glaciers existed immediately between Hazelton and Wrangell, over which we would have to cross.

Flying Over Mountains and Glaciers

At 1.30 p.m. all the planes were in the air and the start for Wrangell was made. The country crossed up to the River Nass was much the same as that which had been traversed between Fort George and Hazelton, but after leaving the valley of the Nass we were obliged to climb to an altitude of about 10,000 ft. to enable us to cross the mountains. On the very crests of the wide ridges were glaciers of immense area, and valleys so shallow that even as late as the time when we crossed they were filled with snow. This area offered absolutely no possibility of landing, and we were distinctly glad when we reached Steward Arm, which indicated that we were nearing the coast. From this point we began to encounter high clouds of increasing thickness, which became greater in number and size as we neared the coast. We were unable for long periods of time to see anything below us at all. In the immediate neighborhood of Wrangell the weather was temporarily clear, and landing was made on Sergief Island at the mouth of the Stikine River at 4.30 p.m. The field was a marsh which was dry at low tide, but unfortunately when we arrived there was about 6 in. of water on it. The surface under the water was firm, and no damage other than a thorough wetting was experienced by us.

We were back in American territory at last and really felt quite at home. The people of Wrangell had come to Sergief Island en masse and welcomed us most heartily. By 7.30 p.m. our planes had been gassed and oiled and all preparations made for the flight to White Horse on the 15th.

The 15th proved cloudy and an impossible day for a flight to White Horse. On the 16th all were ready to go at seven o'clock in the morning, but we were unable on account of local weather conditions to leave the field before noon, and then it was possible only to take-off one at a time from a narrow strip of ground around the center of the field that had not been reached by the tide which was gradually covering the field. Three planes were barely able to get into the air on account of the rapidly rising water. In fact, the water rose so rapidly that Plane No. 1, which was taking-off last, was unable to get off that day.

Plane No. 1 took-off Aug. 17 at 8.50 a.m. The run as far as Juneau was with a favorable wind and under clear skies, but after passing Juneau clouds began to blow in from the Pacific rapidly, and within ½ hr. after leaving Juneau we were flying not over 500 ft. above the water of the Lynn Canal. After passing Fort Haynes, the fog began to lift somewhat, and when Skagway was reached it was seen that the clouds were high enough to permit crossing Chilkoot Pass at an altitude not much exceeding 100 ft. After crossing the summit, the bad weather was left behind, and the flight from the summit of Chilkoot Pass to White Horse was ideal. Landing was made at White Horse, Yukon Territory, at 1.05 p.m., after a very beautiful and interesting trip.

Planes Nos. 2 and 4 took off at 3.00 p.m. the same day for Dawson, to be there in time to participate in the celebration of the Discovery Anniversary, which is held on Aug. 17 every year in commemoration of the Klondyke strike. It was contemplated that Lieutenant Crumrine and I should go along, but unfortunately on the take-off he blew a tire, and by the time it could be mended it was too late to permit our arrival at Dawson before sundown that day. Take-off was effected for Dawson at 6.14 a.m. on the morning of the 18th. Our flight took us over the historic Lake Le Barge and the Yukon trail, which the gold seekers followed in the Klondyke rush. We passed directly over the towns of Carmacks, Yukon Crossing and Selkirk on the Yukon River. From that point we followed the Wounded Moose trail from Pelly over the mountains away from the Yukon River to the valley of the Stewart River, over Stewart Crossing, striking the Klondyke River just south of Dawson by way of Bonanza Creek. At Dawson we were given a most remarkable reception. Everyone who was physically able was out at Faulkner's Ranch to greet us.

Our engines were all running beautifully up to this point, and as no work was necessary on our planes, they were made ready for an immediate departure for Fair-

banks on the 19th. At 10.52 a.m. of that day, all the planes had left the ground, and struck for the headwaters of the Forty Mile River on our way to Fairbanks. To fly from the valley of the Yukon to the valley of the Tannana, in which Fairbanks is situated, it is necessary to cross the Alaskan Range, whose lowest point was fortunately at the very point where our route crossed it in a direct line from Dawson to Fairbanks. It was over this country that we had expected to see the immense caribou herds, of which we had heard so much talk at Dawson, but unfortunately during our entire trip we saw nothing living from the time we left Dawson until we reached Chena Slough. The intervening country was as barren as any we had crossed, there being very little verdure except stunted poplar which clustered on the slopes and in the valleys of the then dried-up waterways.

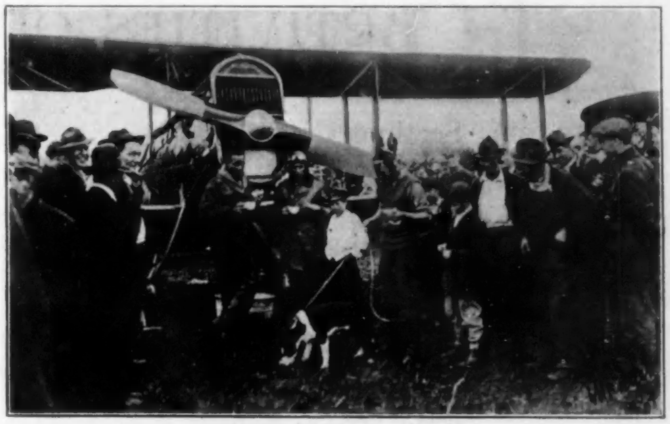
The valley of the Tannana offered a striking contrast to the country over which we had flown, with its green fresh look and its abundant verdure. Landing was effected at Fairbanks at two o'clock, 3 hr. and 8 min. after our departure from Dawson. Our reception was most enthusiastic. Mines and projects for miles around were deserted; everybody had made it his business to be present when the airplanes landed. The landing of the first airplane in Alaska impressed the people of this country as being a great event, and they were prone to give as much credit for it personally, without taking into consideration the wonderful attributes of the modern airplane.

Excellent Condition of the Planes

Fairbanks was the point we had picked at which to outfit and repair planes in case of necessity, and consequently most of our supplies were allocated there; but due to the splendid condition of the planes and the engines, and to the increasing lateness of the season, it was considered advisable to push on the next day to Ruby, our last stop before reaching Nome, our destination. The weather on the 20th, however, prevented our taking-off that day, and on the 21st it seemed that unfavorable weather would bar our further progress. But the weather cleared sufficiently by noon to permit our take-off, which was made at 12.20 p.m. When 15 min. west of Fairbanks we began to encounter rain. We continued to fly through rain for almost $\frac{3}{4}$ hr.; in fact until Harper's Bend on the Tannana was reached. At this point the weather began to clear and the remaining 100 miles to Ruby was made through a clear beautiful sky.

We had been flying down the valleys of the Tannana and the Yukon Rivers during the entire trip. The borders of these rivers for miles, both north and south, constitute the most impenetrable swamps imaginable. Lieutenants Nutt and Crumrine, who were prominent in the search for Lieutenant Niergarth in the Florida Everglades, made the statement that the swamps of Alaska are by far the most formidable they had encountered. After $2\frac{3}{4}$ hr. in the air a landing was made at 3.05 p.m. near Ruby on a sandbar left dry shortly before by the recession of the river.

The Indians on the Yukon had forsaken their season's fishing, waiting for the airplanes to arrive from the east, and were present in great numbers when landing was made at Ruby. We have since been told by persons who were present that the Indians were frightfully perturbed when the planes were swooping about, preparing to land, but after the landing was made and they saw that the airplane is operated by man and not a monster of mythology, they were completely reassured and their curiosity got the better of their fears.



At Fairbanks on the Return Trip from Nome

Our engines had been performing splendidly throughout the entire trip. A landing was made without any mishap and our flight to Nome was planned for the 21st. Unfortunately, the weather on that and the following days was so poor as to prohibit the trip, but at 3 o'clock on the 23rd preparations were made for an immediate take-off with weather showing signs of clearing. At 3.15 p.m. the flight started the last leg of its journey to the northernmost city of the American continent.

From Ruby to Nulatto on the Yukon River the terrain traversed was much the same as that from Fairbanks to Ruby; the same dreary expanse of impenetrable marsh. The flight from Ruby to Nome was hindered considerably by the necessity of flying around small rainstorms. At Nulatto we left the Yukon and started to cross the mountains to Norton Sound. We ran into most disagreeable weather which made it impossible to maintain an altitude greater than that necessary to just clear the tops of the highest peaks, and during the intervening time we were passing through almost continual rain. At last Norton Sound was sighted, and after passing through a short snow flurry, we finally burst again into sunshine, which prevailed for the rest of the trip as we proceeded up the coast from Bald Head to Nome. Landing was made at 5.50 p.m., after about $3\frac{1}{2}$ hr. in the air.

The entire flight from New York City to Nome, a distance of 4502 miles, had been accomplished in approximately $59\frac{1}{4}$ flying hr., at an average of 77.51 m.p.h. After the landing was made, each pilot reported his engine in condition warranting our attempt to return to the United States with our original powerplants.

The people of Nome were as pleased with the fact that we had successfully made the trip as we were, and considered our advent as an exemplification of a means of transportation which can in the near future be turned into channels by which they will be able to surmount a great many of the difficulties that arise with their present poor means of communication.

WORLD DEBT AND PAPER CURRENCY

THE growth in world debts and paper currency has not been checked by the return to peace. The additions to world national debts, which averaged $40,000,000,000 per annum during the war, were $44,000,000,000 in first year following the armistice and $42,000,000,000 in the year just ended, the second peace year. The additions to the world paper currency, which averaged $9,000,000,000 per annum during the war, were $12,000,000,000 in the first peace year and $25,000,000,000 in year just ended.—National City Bank.

ACTIVITIES OF THE SECTIONS

Sections Calendar

Boston
March 18

Buffalo
April 19—Carbureter Performance. F. C. Mock

Dayton
May 3

Detroit
March 25—Relation between the Industry and the Department of Engineering Research at the University of Michigan. Prof. E. A. White
April 22

Metropolitan
March 10—Brakes. H. G. Farwell
April 14—Low-Grade Fuel Carburetion. R. H. Beach

Mid-West
March 11—Storage Batteries

Minneapolis
March 2—Good Roads and Equipment
April 6—Repair Equipment

Washington
March 18—Highway and Highway Transport Meeting
April 1—Aeronautical Meeting
May 6

PROF. C. A. NORMAN of the Ohio State University gave some interesting facts before the Minneapolis Section on Feb. 7 on the subject of Fuel and Fuel Substitutes. He quoted the United States Geological Survey as predicting the exhaustion of petroleum supply with the present rate of use in a very few years, but suggested that the adaptation of the solid-injection engine to automotive use would double the time through which the present supply of petroleum would last. The speaker discussed various fuel mixtures including benzol and alcohol, pointing out not only their chemical and physical properties from the standpoint of desirability as engine fuel, but also their economic feasibility. While it is possible to produce sufficient alcohol from certain crops as far as available land in this country is concerned, the alcohol could not be produced by this method at a cost sufficiently low to warrant the development of an industry for the purpose.

Professor Norman advocates the immediate development of the shale-oil industry believing that it is important that a beginning be made in order that proper processes can be worked out for lowering the cost of production in this field.

At the conclusion of the paper, the Story of Petroleum film, produced by the Bureau of Mines, was shown.

The Metropolitan Section held a meeting on Feb. 17 at Cooper Union, New York City, at which Ethelbert Favary presented a two-part paper on The Calculation of Motor Vehicle Frame Stresses, in connection with which materials were tested in the laboratory on a machine having an automatic recording attachment showing elastic limit, yield-point, elongation and ultimate strength, and on the testing of engines by dynamometers, manographs and O'Kill pressure indicators. In the laboratory tests were made disclosing the ratios of maximum pressures to compression pressures at various throttle openings, as well as the maximum pressure with cylinders thoroughly scavenged. At the dinner preceding the technical session, Magistrate House of the Traffic Court of New York City gave a talk on matters of importance to the automotive engineer.

R. E. Lippert told the members of the Cleveland Section something of the various systems of drying used in painting processes at the meeting of that Section held on Feb. 18.

The Fuel Problem in Terms of Miles per Gallon was the subject presented by O. C. Berry at the Detroit Section meeting of Feb. 25. On the same evening the Boston Section held a session at Springfield, following out the program of this Section to hold meetings at various automotive centers in New England.

On Feb. 25 the Pennsylvania Section held a session at which the general subject was automotive vehicle equipment. The Buffalo Section discussed Temperatures in Internal-Combustion Engines at its meeting of Feb. 23.

Members of the Society resident on the Pacific coast, in response to the invitation issued by the local committee at San Francisco, attended the first of a series of luncheons at the Palace Hotel in that city, 56 being present. Lawrence P. Wagner of the Standard Oil Co. addressed the group on the subject of lubrication. The formation of a Section of the Society in San Francisco or the holding of a series of technical meetings there under the auspices of members of the Society was discussed. Another luncheon for further discussion of this matter is scheduled for this month.

FITS FOR CYLINDRICAL PARTS

THE classes of fits which apply to cylindrical parts may be approximately summarized as follows: (*a*) running fits, where one part must revolve freely; (*b*) sliding fits, where one part must slide freely; (*c*) push or dowel fits, where neither part is required to revolve but where both parts must assemble readily and be held in alignment; and (*d*) force, driving or shrinkage fits, which are made with pressure or by shrinkage and used in assembling parts which must be held in fixed positions.

The amount of the minimum clearance for a running fit is dependent, to some degree, on the length of the bearing; a long bearing may have a somewhat greater clearance than a short one. The proper length of the bearing depends on the load and the material used in the bearing. The load controls to a large extent the diameter of the bearing. The first step toward standardizing the minimum clearances is to determine the most common material employed in making the bearings, and to establish standard lengths of bearing for the various diameters of shaft. The exceptions which will inevitably develop must, of course, be treated on their own merits. Take, for example, a long feed-screw or a long bending roll which is supported at the ends. Regardless of the diameter or the length of the bearing, greater minimum clearances than the established standard would be required. If the number of similar exceptions is appreciable, supplementary standards can be developed to meet them.

Another factor which must be considered before the standards can be safely established, relates to the conditions under which the parts must operate. Thus, if the parts must operate when subjected to higher or lower temperature than normal shop temperatures, due allowance must be made. On the other hand, if such temperatures are the exceptions, the corresponding clearances must be exceptions.—Earle Buckingham in *Machinery*.

Dilution of Crankcase Oil[1]

By William F. Parish[2]

Illustrated with Charts

DURING the past few years the petroleum industry has been able to meet the tremendous demands for internal-combustion engine fuels only by turning out products that have been becoming gradually heavier and less volatile. The use of these heavy fuels in engines designed for the use of the lighter and more volatile fuels has brought about an unbalanced condition of the fuel, the engine and the lubricating oil. This condition has developed the dilution problem. Dilution, as a problem, has been brought forcefully to the attention of engineers during the last 2 years. The condition existed before but, due to the fact that the fuels in use were more volatile, the thinning of the lubricating oil did not bring it to a point where it would not support lubrication. In the four-cycle engine leakages always occur, irrespective of the nature of the fuel used. The effects of these leakages on the lubricating oil differ. With casinghead gasoline, natural or artificial gas, the leakages do not combine permanently with the lubricating oil and there is no dilution.

Dilution of the lubricating oil in an engine operating on the heavier of the liquid fuels is due to three causes: (*a*) the gas mixture escaping past the piston-rings during the compression stroke, (*b*) the lubricating oil on the cylinder walls, which has become diluted with fuel during the admission and compression strokes, leaking back into the crankcase, and (*c*) decomposition or "cracking" of the lubricating oil that has been thrown against the underside of the pistons or other heated surfaces.

The piston travels through two revolutions to allow the completion of the four cycles necessary to produce the power. A short discussion of what takes place in the cylinder and crankcase will set forth clearly the various stages leading up to dilution. For example, consider a clean engine and new, clean oil. The piston is on its upward or exhaust stroke. It is during this stroke that the cylinder wall receives its best film of lubricant, the oil being carried up by the rings and piston. The return or admission stroke creates a partial vacuum in the cylinder. This brings in the fuel mixture, which comes in contact with the film of lubricating oil on the cylinder wall. Some of the fuel in the mixture combines with the lubricating oil, reducing the body of the film as it becomes diluted. The diluted oil has more of a tendency to drain back into the crankcase than undiluted oil. During the return stroke the fuel mixture is compressed to as high as 35 lb. per sq. in. The greatest dilution of the film on the cylinder walls occurs during this stroke. Also, during this stroke the film of oil should be the strongest, to seal the space between the rings and cylinders properly. With all four-cycle engines some leakage of the fuel mixture takes place during the compression stroke. The amount of leakage depends upon the mechanical fit of the rings and the perfection of the seal formed by the lubricating oil. The mixture that escapes has all of the component parts of the fuel mixture in the cylinder at the time of the leakage and the fuel content is absorbed by the lubricating oil.

During the first part of the power stroke the film of oil on the upper part of the cylinder walls is largely destroyed, the volatile products combining with the fuel. The lower part of the film resists the reduced heat of the gases to an increasing extent as the gases expand. Carbon is formed as part of the decomposition of the lubricating oil during this stroke. Carbon deposits are heaviest where destruction of the film is greatest. There is practically no leakage of unconsumed fuel except as it has combined with the lower oil film. There is less possibility of leakage of fuel or of the unconsumed heavy ends during the power stroke than during the admission and compression strokes. At the completion of the power stroke, the oil film on the cylinder walls is in the poorest condition. This is remedied by the return or exhaust stroke when a new supply of oil is put on the walls.

Crankcase Conditions

During every throw of the cranks, oil is splashed up inside of the pistons. The heat cracks the oil, liberating a volatile portion which flows into the crankcase and aids dilution in exactly the same way as the leakages of the same boiling-point fractions from the fuel. The amount of diluent in the oil after a period of operation depends upon the nature of the fuel, the kind of lubricant and the general heat of the engine and the surrounding atmosphere.

There is no dilution when the engine is operated with natural or artificial gas. In this case the lubricating oil gets heavier. If the heaviest of the fuel distillates is used in the same engine and under the same conditions, the leakages combining with the oil make a mixture of various proportions of lubricant and fuel, the exact amount of each entering into the mixture depending upon the nature of the fuel being used, the original body of the lubricating oil and the temperature at which the oil and the engine operate. This mixture will remain constant with the same fuel, oil and engine temperature. As the engine operates at higher temperature, more of the fuel distills off and the proportions of lubricant in the mixture in the crankcase are consequently greater and it is thicker. Conversely, when the engine operates at lower temperature, more of the fuel is retained and dilution is, in consequence, greater and the mixture is thinner. Dilution difficulties are, therefore, more pronounced in winter than in summer. The amount of lubricant that works into the upper parts of the cylinder and is consumed depends upon the body of the lubricant. Thick oil works up very slowly and is, consequently, consumed less rapidly than thin oil.

The lubricating oil is an important factor in the dilution problem. Thick oil resists the dilution of the film and therefore drains less. Thick oil presents a more perfect seal and checks the escape of the gas during the compression stroke. Thick oil, as a rule, will decompose at a higher temperature than thin oil; therefore it will resist destruction better. In the same engine, with the same fuel and temperatures, for the same period of time, dilution will be greater with the thinner oil.

The fit of the piston-rings in their grooves and their free action against the cylinder walls control to a great

[1] Paper read at the annual meeting of the American Petroleum Institute, Washington, Nov. 18, 1920.

[2] M.S.A.E.—Consulting engineer, Chicago.

extent the amount of leakage of the diluted film and the gas. A more perfect lubricating seal can be produced by applying new oil directly to the rings, as in the practice of lubricating the larger gas engines. The new lubricating oil should be selected on the basis of its condition in the engine, so that it can work properly with any increased clearances that are due to operation and wear. By carefully controlling the mechanical and lubricating conditions, dilution in the same length of time will be less but will not be prevented.

Over-lubrication results if too much lubricating oil works up to the top of the cylinders. This keeps the tops of the pistons, the valves and spark-plugs "wet." Wet spark-plugs are insulated and their effectiveness is reduced. If the spark-plug ceases to function, due to this condition and to the after-effect of fouling, where there is an excess of wet carbon, all the fuel entering that cylinder is wasted. The cylinder becomes cooler and the fuel condenses more readily. Leakage and draining will increase and dilution become more rapid from this cause.

Friction and Power

The changes that take place in the fuel consumption of an engine operating under test conditions are partially due to temperature and its effect upon the body of the lubricating oil and to dilution of the lubricant. The method of determining the amount of dilution in oil drained from the engine at various periods varies with different laboratories. All of the methods proposed do not allow the removal of the exact amount of diluent carried by the lubricant. This is due to the diverse nature of the different lubricating oils and to the manner in which they act under the methods of treatment to remove the diluent.

In the experiments described each lubricating oil tested was treated individually. Samples of the oil were made with different fixed amounts of kerosene, the specific gravity of each sample being determined. This permitted a chart to be made showing the relation of specific gravity to percentage of dilution. By securing the specific gravity of the same oil taken from the crankcase, it was possible to determine the dilution. These samples were tested for viscosity on the Saybolt universal viscosimeter at 100 and at 120 deg. fahr., the average temperature of the oil going on to the bearings having been determined as being 120 deg. fahr. These data allowed the making of a chart of viscosity as related to percentage of dilution. When a sample of diluted oil was removed from the engine, it was immediately tested for viscosity at 120 deg. fahr. and then for check at 100 deg. fahr. From these findings the dilution could be readily secured. Finally, as a check, a mixture of the fresh oil and kerosene was made and a complete distillation secured so that the usual chart could be made of percentages against temperatures. The figures secured by distillation of a sample of the oil removed from the crankcase were plotted over this chart. The distillation charts show that the used oil from the engine contains more volatile products for the first half of the curve, but apparently more heavy products for the last of the distillation range.

Fig. 1 shows the curves already described. The data given on Fig. 2 are most interesting and have been made from a great many tests. This is a standard chart to show the influences of the various factors. The engine is required to develop a steady and fixed brake-horsepower at 1500 r.p.m. The engine is perfectly clean for the test and has been filled with new oil. This oil has been tested as described and shown in Fig. 1, so tables are ready to check the dilution. An excess of 4 oz. more than the regular filling is put into the engine. At the end of 1 hr. oil to the amount of 4 oz. is removed from the circulating system supplying the bearings. This sample is immediately tested for viscosity at 120 deg. and 100 deg. fahr. on the Saybolt universal viscosimeter. The specific gravity is then taken at 60 deg. fahr. At the end of the second hour a second sample of oil is removed and the first sample is poured back. For the remainder of the tests there is always 4 oz. of oil out of the engine being tested for viscosity and specific gravity, so the percentage of dilution can be determined.

The two viscosity curves near the bottom of Fig. 2 represent the actual viscosity of the samples removed hourly. The amount of dilution shown on the lower curve is taken after comparing the viscosity to the percentage of dilution on Fig. 1. Specific gravity is used as a check. It transpired that more accurate results were secured by operating on the basis of the viscosity determinations, as the viscosity could apparently be determined much more accurately than the specific gravity.

The temperatures in one series of tests were very accurately taken by thermocouples attached to the bearings and in the oil lines. The line on Fig. 2, showing bearing temperature rise above the temperature of the incoming oil, indicates clearly the changes that take place in the engine because of the changed condition of the lubricating oil due to temperature and to dilution. The line of bearing temperature must be compared to that of friction-horsepower, which starts off high when the oil is cold and drops as the oil becomes thinner due to heating and dilution. The changed friction-horsepower shows the proper influence on the fuel consumption after the first hour.

There are two remarkable features about all the charts that have been made on this work. First is the low fuel consumption during the first portion of the run, with its rapid rise during the first hour. Second is the gradual upward trend of all lines toward the end of the tests. The obvious explanation of the comparatively low consumption of fuel during the first part of the first hour's run is that when the oil is cold and undiluted it acts as an almost perfect seal, preventing leakage of the fuel mixture and allowing the engine to develop its full power and speed with a minimum consumption of fuel. Tests have been made in developing a method of applying new oil directly to the piston in an attempt to overcome dilution difficulties. It has been found that application of new cold oil will reduce the fuel consumption as much as 10 per cent, compared to ordinary lubrication with diluted oil. This seems to check the peculiar hump on the fuel-consumption chart.

The high fuel consumption at the end of the first-hour period is due undoubtedly to the fuel leakage caused by the breaking down of the seal as a result of dilution and by the high internal friction of the new oil. The gradual drop in the line to the sixth-hour period is caused by the more free operation of the lubricant, as indicated by the reduction in temperature of the bearings and the reduced friction of the engine. The rise in fuel consumption after the sixth-hour period is clearly caused by a gradual thickening of the oil due to the carbon and metal deposits it is carrying with it. The viscosity and gravity readings have been taken on the oil as it was taken from the engine. During the last period it was determined that by filtering the foreign matter out of the samples the viscosity was somewhat

more constant, but as the oil in the engine operated with this deposit, it was put through the viscosimeter in this condition. As the bearing temperature rose, after the tenth-hour period, this affected the amount of dilution in the oil as shown by the increase in viscosity with less dilution.

It is well known that in the Air Service oils must be removed from engines after periods of about 5 hr. operation. The reason for this is that the oil becomes so thick that it will not operate properly in the lubricating system. This thickness is caused by carbon that forms through the decomposition of the oil and then gets into the circulating oil. It is perfectly reasonable to expect the friction of the engine to increase as the oil gets thick

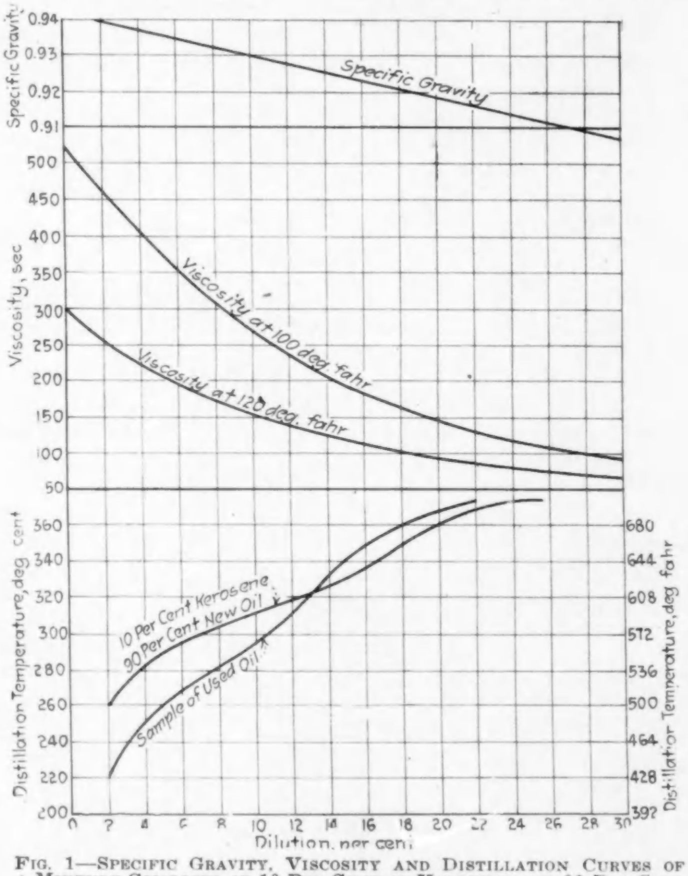


FIG. 1—SPECIFIC GRAVITY, VISCOSITY AND DISTILLATION CURVES OF A MIXTURE COMPOSED OF 10 PER CENT OF KEROSENE AND 90 PER CENT OF LUBRICATING OIL

from any cause. In the tests represented by Fig. 2 such increased friction is indicated.

RECLAMATION OF USED ENGINE OIL

Processes developed for the reclamation of used oil from internal-combustion engines utilize the heat from steam. The results that can be obtained by treating diluted and carbon-contaminated oil in one of these systems will help to promote a general understanding of the subject. Oil collected from a number of motor trucks was placed in a reclaimer similar to those used by the Air Service during the war. Samples of the dirty oil put into the reclaimer and of the oil removed every hour during the reclamation process were carefully examined. Table 1 gives the details of the dirty oil and the reclaimed oil.

TABLE 1.—USED AND RECLAIMED OIL

	Dirty Oil	Reclaimed Oil
Specific Gravity, deg. Baumé	28.4	26.2
Flash Point, deg. fahr.	140	320
Fire Point, deg. fahr.	180	385
Pouring Point, deg. fahr.	Zero	25
Viscosity, Saybolt sec.		
At 100 deg. fahr.	99	228
At 130 deg. fahr.	68	117
At 210 deg. fahr.	42	49
Carbon (Conradson), per cent	0.56	0.34
Dilution at 600 deg. fahr., per cent	16	4
Water, per cent	1	...
Ash, per cent	0.170	0.003
Sediment, by weight, per cent	0.44	None

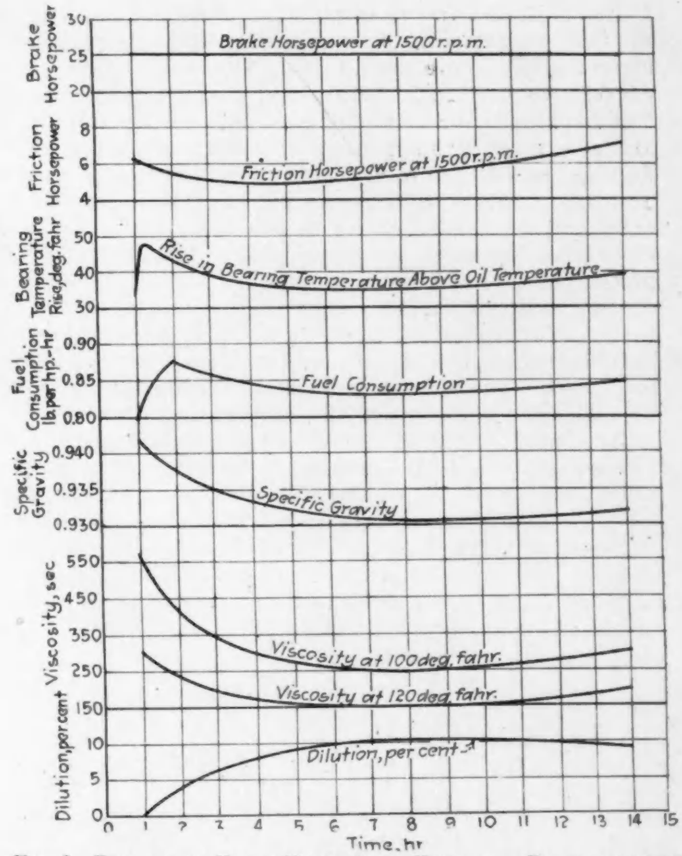


FIG. 2—RESULTS OF TESTS MADE ON AN ENGINE TO DETERMINE THE EFFECT OF DILUTION OF CRANKCASE OIL

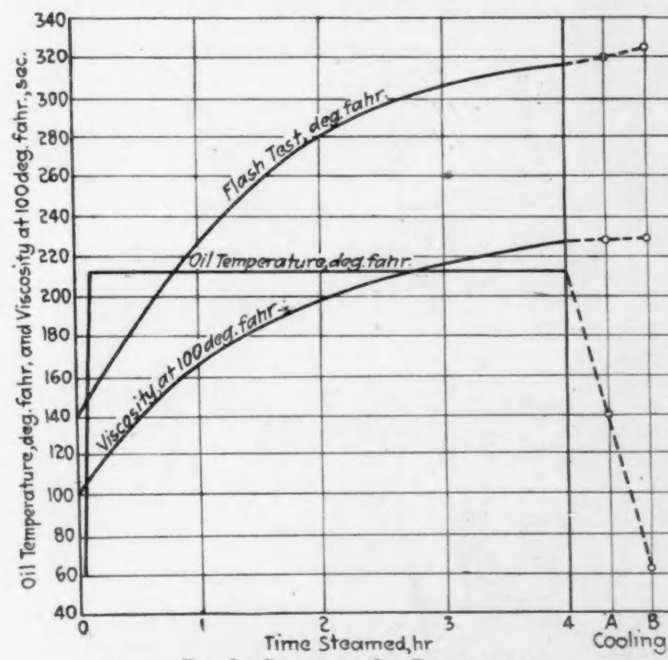


FIG. 3—CURVES OF OIL RECLAMATION

Fig. 3 shows the flash point and the viscosity of the oil in a reclaimer as it was undergoing the process of steaming to remove the diluent. The temperature of the oil was 60 deg. fahr. before the steam was turned on. The temperature rose to 212 deg. fahr. in the first 7 min. and remained at that point until the steam was shut off. During the next 30 min. the temperature fell to normal. The total dilution of the dirty oil was 16 per cent as determined by distillation up to 600 deg. fahr. The total amount of sediment by weight was 0.44 per cent. The process removed all but 4 per cent of the diluent and all of the sediment. The outstanding feature shown by Fig. 3 is the constant increase in flash point above the temperature of the oil, the diluent being carried off by the steam. There is an increase in the flash point after the steam has been turned off and the oil has cooled down. After steaming, the oil had a flash point of 305 deg. fahr. Two days later, three samples taken directly after the steaming process each showed a flash point of 325 deg. fahr.

The process as developed to date is not perfect, but indicates what can be accomplished in the way of reclamation. It has been developed sufficiently to show that reclaimed oil is a satisfactory lubricant for use in internal-combustion engines.

THE DISCUSSION

W. F. Parish:—With reference to Fig. 2, if this were any kind of machine other than a gasoline engine, as the cold oil got into action the consumption of fuel would be at its highest instead of at its lowest point. The power curve should start in high and fall off gradually as the temperature of the oil increased, in tests on these gasoline engines. It does not do so. The only reason for the fact that the consumption of fuel per brake-horsepower-hour is 10 per cent lower on these curves at a time when it ought to be the highest, if we take the rules of lubrication and of mechanics into consideration, is that a better piston seal is produced in that engine at a time when the oil is cold and undiluted. No other conclusion is possible. If there were fuel leakage, if the rings were continuously tight and we could get a perfect mechanical seal, the fuel curves would start high with the cold oil, dropping as the oil temperature increased, but the fuel consumption would be 10 per cent below the entire present curve. Conversely, if the rings were very much out, there being no mechanical or lubricating seal, the curve would show a very high fuel consumption per horsepower-hour, representing the greater amount of fuel required to operate the engine plus the large loss of fuel during the compression stroke.

In the discussion of my paper on Castor Oil Versus Mineral Oil for the Lubrication of Airplane Engines, presented before the Mid-West Section of the Society of Automotive Engineers recently, a speaker stated that his company had a system of chassis lubrication by which oil was forced in under pressure to every point, including the engine. His company had been experimenting for many months. They had determined that by feeding as little as 22 drops per min. per cylinder to the piston-rings they could not only support lubrication perfectly but that this actually allowed the engine to operate with 10 per cent less fuel per brake-horsepower than when the same engine was lubricated with diluted oil splashed up from the crankcase.

We are building an engine that during the most important cycle, the compression stroke, has a basic defect that allows actual leakages of fuel past a supposititiously light seal. We are operating almost 10,000,000 four-cycle automobile, tractor and stationary gas engines that have this wrong basic principle, where worse results are produced as the engine wears. From a lubricating standpoint, we cannot improve the situation very well in these engines as they exist, because the heavy ends of the present fuel get into the crankcase and still further lower the seal effectiveness of the lubricant.

My men examined all the motor vehicles they could handle during last winter and continued the work well into the summer. They requested drivers to continue the use of the same gasoline from the same filling station for the period during which we wished to observe dilution conditions in their cars and trucks. Samples of oil were taken from time to time, reports were secured from the Weather Bureau of the average temperature and humidity of the day, and the oil analysis work was done in the same laboratory. In investigating in this manner the condition of everybody's oil and of everybody's gasoline, enough information was secured to plot a chart showing the amount of dilution to the percentage of iron taken out of these used oil samples.

Some think that the condition does not warrant very much thought. If it is necessary for a lubrication engineer to lubricate a piece of machinery that requires an oil of 300 Saybolt sec. viscosity and he has to use an oil of only 45 Saybolt sec. viscosity at 100 deg. fahr., which is practically gas oil, he would know that the oil was entirely too thin to support lubrication. Under forced feed to the bearings lubrication probably can be supported down to that degree of thinness; but, with the cylinder walls and the grooves and the surfaces of the piston-rings, points which affect the economy of the engine as to the leakage of the gas as the oil gets thin, we can expect greater consumption of oil and gas and more wear. The wear can be determined by taking samples of oil and examining them for iron. Charts for the same car show that as the weather temperature increased during the week the wear decreased, because the oil became thicker and prevented abrasion. As the weather gets colder, dilution increases; the oil holds more of this diluent, up to 50 per cent, and the law is established that as we increase the dilution we increase the wear, which is indicated by the amount of iron taken out of the samples.

The tendency of these curves merits some consideration. Oil is at its best on a forced-feed system when the oil is thin enough to just keep the surfaces apart. As indicated by the temperature of the bearings, the friction is much less with the thinnest oil. Therefore, dilution and the thinning of a thick oil with heat increase the efficiency of the engine by reducing the mechanical friction load. That is, when starting a machine, the frictional power is the greatest with cold oil and the curve comes down as the oil becomes thinner through heat and through dilution.

There is a condition, however, which the oil reaches where it will not support lubrication and abrasion takes place. That point is changing constantly on the cylinder walls and in different places not under forced feed. Gradually, the area where abrasion takes place increases as the oil becomes thinner and will not support lubrication or keep the surfaces apart. It is natural to suppose, if dilution is increased in an amount necessary to make the oil too thin to support lubrication, that then we will have a gradual increase of frictional power. The effect of fuel upon the lubricant brings about general rules of lubrication which are entirely the result of the practical observations of many people.

The German aviation service used a lubricating oil of

750 Saybolt sec. universal viscosity at 100 deg. fahr. and about 54 Saybolt sec. viscosity at 212 deg. fahr. for their Zeppelin engines and for the entire aerial machinery during the war. The French and English used mixtures of American oils much thicker in average body. In the American Air Service we used oils materially heavier, and many of our aviators thought they must have something much thicker than we were disposed to give them. The engines of all three services were practically interchangeable. They all presented about the same lubrication problem; yet the German service, for about 5 years, used oil that we could not use in the American engines because it was too thin. The reason these three services demanded and required different kinds of lubricating oil for practically the same machine is traceable to the fuels they used. Germany had more volatile fuels for its aviation service during the war than any other country. The oil the Germans used became heavier in the engine, as we could determine very well from airplanes that were shot down from time to time. The French had fuel that was less volatile than the German fuel and we had to get along with fuel of still heavier end-point; consequently both American flying machines and those of the Allies required heavier lubricants to offset the dilution effects of the heavier fuels.

There is little use in presenting a serious problem unless some solution is offered. Before considering what can be done to solve this problem, we must answer some of the statements made by a number of men engaged in the oil industry that crankcase oil dilution conditions cannot be serious because they have not been called to their attention. One large motor-trucking company has concluded from its records of the year just past that 85 per cent of its engine service jobs are traceable to lack of lubrication due to this dilution problem. That percentage has been confirmed by three of the large producers of motor trucks. The motor-truck service people evidently know more about this problem than we are willing to confess we know. We know of the demands made for heavier oil, which should show us what is wrong. The motor-truck people have the impression that the condition can be overcome to some extent by draining and replacing the oil about twice as frequently as is now recommended in their instruction books. One difficulty is that dilution sometimes occurs to the full extent, on a cold day, within the first hour of the first day or the first 50 miles; so, if automotive engineers issue general instructions that oil is to be drained as soon as dilution takes place to a certain degree, our motor-truck drivers will spend most of their time under the trucks. Frequently draining the oil will undoubtedly have considerable cleaning effect on the engine, but it will not prevent dilution. The industry was actually short of heavy engine oils during 1920. Using more oil per 1000 car-miles in an attempt to overcome dilution will bring about a shortage without materially improving conditions unless an immediate reform is made in the practice of throwing used oil away.

In the American Air Service, reclamation stations for the reuse of aviation oil were established. For 4 years preceding the period of our entering the war, the Allies and our enemies were using oil in their aviation engines and, at periods of about 5 hr., taking it out and throwing it away because the oil was supposed to have become worn-out. Dilution was not a problem because of the grade of fuel used, the oil was heavy, and produced much carbon, and after 5 hr. as a rule became so thick that the pumps would not handle it.

Considering the number of engines that the United States Air Service expected to build and operate, according to our factor of consumption of oil per horsepower-hour, there was not enough oil in the country to support the program. Our supplies had been depleted by the extravagant method of the Allies in operating their machinery during the war period. It was necessary to institute a reclamation program and, against the advice of a large number of refiners, this was done. Many believed that it would not be possible to reclaim oil that had been used in an aeronautic engine, bringing it back into a condition that would make it suitable for such use again, but the possibility of reusing a vast amount of oil was great enough to encourage us to institute the program.

Oil Reclamation Method

The system was very simple. We put the oil and water into steam-jacketed tanks and blew steam in; soda ash or "gold dust" was sprinkled on the surface of the oil, thus forming emulsions and obtaining a precipitation of carbon, iron and dirt, after a period of rest. In an hour or two we obtained clean but black oil. The steaming had removed the 2 or 3 per cent of the diluent that came from our volatile aviation gasoline. The recovery of good oil in extreme cases was as high as 85 per cent and for 5 months we obtained a 75 per cent recovery of 50 per cent of all the oil used in the Air Service. The other 50 per cent was burned in the engines. If the war had continued and we could have installed oil-reclaiming stations in Europe, we would have had the equivalent of many refineries right back of the battle front.

If we should reduce the end-point of the gasoline to help the situation, which would mean reducing the amount, in a year or so we would be forced by the demand for fuel into exactly the same situation that is facing us today. We can reduce the actual fuel per brake-horsepower hour required by these engines if we force new clean and cold oil directly where it is needed to preserve the sealing required to prevent leakages, but we cannot supply such a system to the present 10,000,000 engines. In his paper on Dilution of Engine Lubricants by Fuel,[3] G. A. Kramer recommends a device for the restoration of engine oil that can be attached to the engine. Such a device has been designed. It will treat the oil in the engine, bring the oil back to its original body, allow the use of originally thinner and cheaper oil, recover the fuel vapor and put it back into the intake manifold. I have seen one such device that looks extremely interesting. It consists of a small reclamation plant under the hood that is no larger or more complicated that the vacuum fuel system. Reclamation apparatus should be installed wherever there is a fleet of trucks. The reclamation apparatus manufacturers are engaged in an attempt to develop apparatus that can be used generally. For the future and to care for the engines already built, the dilution problem must depend for its solution upon apparatus that can be attached to the engines to remove the diluent and reclaim the oil and upon frequent removals of oil from other engines, such oil to be passed through recovery stations so that it can be reused.

Chairman H. M. Crane:—The automotive engine was first designed to make use of a dry fuel. I probably was one of the first users of gasoline in this country, as I operated about 1887 a naptha stove for which we bought

[3] See The Journal, February, 1920, p. 123.

stove gasoline or stove naptha for 10 cents per gal. Gasoline was a by-product in those days.

We have reached a condition now in which we are not operating with dry fuel but with an absolute liquid in the cylinders. This has changed the problem entirely and I feel nearly as helpless as Mr. Parish does regarding the situation, in view of the large number of cars which are being operated. As an automotive engineer I do not wish you to believe that I think these cars are perfect or anything like it. They are representative of bad design in many ways, and of very inferior construction, which is even worse. If the whole secret of developing power lies in the type of piston and cylinder, according to our aviation experience, there are hardly any cars in existence today that are properly constructed. They can be properly constructed. We had occasion to overhaul a car that was delivered to its present owner in 1912 and has been driven commercially in the owner's service with the oil and gasoline that his chauffeur bought. An examination of the pistons and rings in that car indicated that the exact clearances that were built into the engine in 1912 still existed. The cylinders were 4.375 and the pistons 4.372 in. in diameter. The reason was that the pistons were extremely long, and were properly lubricated. That engine is in use with the same manifold and the same heating devices that it had originally and, so far as we know, there is no great trouble; there is certainly not enough to influence dilution because, after 44,000 miles of operation, we did not find it necessary to disturb the adjustment that was built into the car in 1912. That is an example of what can be done with good workmanship and good material; but it cannot be applied to the cars now outstanding. The same thing is equally true regarding the addition of such things as the pressure oil feed to the cylinder walls. That undoubtedly would be a great help to the cars that have cylinders that are not round or straight, or pistons and rings that do not fit.

One of the difficulties in the early days was to make the piston pump things down and not up. That is, the oil was fed, for purposes of simplicity, in such a way that it was drawn up instead of down and reached the upper end of the piston. The result was that in all designs of pistons, rings and other details, they were made with the object of pushing the oil back again. That was fine so long as we had to deal with nothing but the oil, but now we are dealing with the liquid part of the fuel that is fed into the cylinder. We cannot distinguish between the liquid part of the fuel and the oil and we get the conditions that Mr. Parish has described. This may require an entirely new scheme of oil feed, but it is all a part of the question raised by the use of heavy fuel. During the war we started with the design of an engine to run with castor oil. The use of castor oil was one of the reasons for the rapid change in the engine that was noted by pilots in the service; that is, castor oil is a very fine lubricant of the machine, but it resembles linseed oil in that it oxidizes and becomes very thick and gummy. We could see no reason for using castor oil. We happened to be using for similar work a mineral oil of about the same viscosity as castor oil. That oil, in 1916, was a commercial and not a special oil. We did not have it manufactured to suit our own ideas of the oil needed. We kept on using it, and we were testing our own engines with commercial motor-car gasoline. Mr. Parish's work during the war caused him to believe that there was not a sufficient supply of oil of that high viscosity, and he determined the Liberty oil specifications, which were 85 Saybolt sec. I think, at 210 deg. fahr. Finally, the time came when we were asked by the Government to use Liberty oil for lubrication during our tests. We made tests of it, which exactly bear out what Mr. Parish stated with regard to the use of oil in Europe. We stated that if we used commercial gasoline, we would have to use thicker oil to protect the pistons and cylinder walls and, if we attempted to use motor-car gasoline with Liberty oil, we would have an excessive loss of engines during tests due to scored cylinders, or we would have to extend the running-in time of those engines to double the ordinary period to arrive at the same result. As each engine we were testing was using from 50 to 70 gal. of gasoline per day and toward the end we were building 60 or 70 engines per day, although they were using only $1\frac{1}{2}$ qt. of cylinder oil per hr., it seemed to me better to use the gasoline of the lower grade in greater quantity, rather than the oil of the lower grade in greater quantity; that was my idea of economy at that time.

Dr. Dickinson, of the Bureau of Standards, has done much interesting work on aviation engines during the war, and also on various types of car engine. He finally determined to make a study of what actually occurs in the fuel-feed system of an engine. Many of us have thought we knew what occurred, but nobody had actually seen it. He succeeded in making a glass manifold of a type of glass that would resist heat, and in actually taking motion pictures of the fluid flowing through the manifold. I say "flowing" very advisedly, because that is what it does. It is interesting to witness visually what Mr. Parish has described as the cylinder conditions in the engine; that is, that the cylinder is not now fed with a dry mixture at all, but with a mixture of air and liquid.

One of the handicaps that automotive engineers have met in their own industry in promoting economy and conservation of fuel has come from the commercial point of view. It is a perfectly fair point of view, that if the public are satisfied with what is being given them, that is the answer. I think we cannot say that this view is not right in ordinary commercial activities. Two of the largest builders of automobiles in this country are found in that class. The public continues to buy their product in large quantities, they have not seen any reason why they should improve it in gasoline consumption and they are by far the largest users of gasoline.

On the other hand, this is not a commercial problem at all. The problem is whether we are going to have any industry, either an oil or an automotive industry, within a few years; in view of this, the automotive engineers feel that they cannot wait until the public demands improvement. We must try to obtain improvement before the public demands it. I hope that the oil men will feel that when we come to them with our problems we are coming with that point of view. We trust that they will feel that the apparent satisfaction of the public with the gasoline they are receiving is not necessarily the final answer; that, if by cooperation the engineers of the two industries can get a greater ton-mileage per year out of the gasoline supply, it is something that ought to be done. I will say for the Society of Automotive Engineers that we will go to any extent that we can in aiding improvements in every direction in our own use of fuel and in cooperating with the petroleum industry as to the best and most economical type of fuel for the various types of work that we have to do. I hope that the oil men will come to us in the same way and put their side of the case before us, and if we do not understand it, persist until we do understand it. I think many of us

do understand the difficulty of meeting the excessive demands for fuel at present, and we must realize that the great American public has never been accustomed to conservation. If our two industries can educate the public to be more careful in its use of fuel and to get more good out of what we provide, we certainly ought to do it. We do not try to get the public discontented with what it is getting from the oil industry and I think the representatives of the oil industry do not try to get the public discontented with what it is getting from the automotive industry. We do not want to start the public off on any line of demand that we do not know in advance can be reasonably met. That is why it is so important for us all to get together and find out now if we can, and certainly as soon as we can, what is the best line for the two industries to follow in cooperation, toward the result we all want to reach.

R. D. LEONARD:—Our figures indicate that, so far as gasoline consumption is concerned, of the 7,000,000 automobiles in use approximately 6,000,000 are passenger cars and 1,000,000 motor trucks; and that the trucks are using approximately six times as much gasoline per unit as the passenger car? That means that the consumption of gasoline in the country is practically equally divided between motor trucks and passenger cars.

I have gathered from Mr. Parish's remarks that the dilution problem, so far as the end-point of gasoline is concerned, is intimately associated with the viscosity of lubricating oil. As the end-point of gasoline goes up, the viscosity of the oil used must be greater. Our tests indicate that a motor truck uses about twelve times as much oil as a passenger car. In all the samples of crankcase oil that we took from our trucks we did not find a very high percentage of "volatiles"; the average was not in excess of 5 per cent, which was conceded to be not very detrimental. Does the automotive industry recognize that the problem of the motor truck is different from that of the passenger car in this respect?

CHAIRMAN CRANE:—There is no question that the problems are different, and that the automotive industry recognizes them as being different. The use of the greater amount of oil in the truck as compared with the passenger car is explained by the more intensive service of the truck. The truck engine is loaded to a far greater percentage of its total horsepower capacity per hour than the passenger-car engine is; in fact, the latter, as it is used in this country, very rarely reaches one-third of its maximum capactiy. That also applies to engine revolutions. The normal passenger-car engine runs from 500 to 700 r.p.m. as against a truck engine running from 1200 r.p.m. up. That can be determined by comparing a Ford truck with a Ford touring car. The ratio is nearly 2 to 1. That is the reason for the excessive use of lubricating oil, comparing the two jobs. The larger proportion of passenger cars are laid up in the colder months. On the other hand, the truck is nearly 100 per cent an all-the-year-around vehicle and for that reason experiences difficulty in winter, when the greater amount of trouble with the dilution problem is experienced. The trouble comes almost entirely in starting in cold weather, when an amount of gasoline up to three or four times that required in normal running is necessary to produce an explosion in the cylinder. The main point in regard to the truck engine is that it is used far harder than the passenger-car engine, and therefore requires more oil.

MR. LEONARD:—Does that modify the dilution problem itself? When adding fresh oil, one is adding all the time to the viscosity.

CHAIRMAN CRANE:—Certain cars today lose oil so fast that dilution is no problem at all. That is, they do 250 or 300 miles per gal. of lubricating oil without dilution; to cars of that class dilution is no problem whatever. There is no excuse for any passenger car doing less than 1000 miles per gal. of cylinder oil.

E. PLANCHE:—The engines used in trucks are much larger than the engines used in passenger cars; consequently they require more oil.

CHAIRMAN CRANE:—That is another way of saying that on the average they are developing more power.

H. L. HORNING:—In the motor truck the load factor is 2½ times as much as in the motor car. The motor car will skim along the road at 15 per cent of its maximum power and some do better than that. With the truck, one thinks of it as being around 40 per cent at the speed at which it usually travels. This means that the truck piston and the truck crankcase oil are at a higher average temperature because of both the load and the speed. One of the factors that is very little recognized today in the design of motor cars and trucks is that bearings cannot be maintained in a truck unless the crankcase bottom is exposed to the air passing by it. That is also very largely true in the case of the tractor. It is a very important factor in keeping the oil cool. With the higher temperatures of the piston, the viscosity of the oil is reduced and therefore its use must become affected.

With motor car engines much attention is given to smooth running. With truck engines the tendency is for a demand to be put upon the driver for results. The driver then does the next best thing; he throws fuel into the system; the fuel has a tendency to break down the lubrication oil. That has nothing to do with the relative fuel consumption of the vehicles, because that is based on factors outside of those considerations. The obvious way to cut down lubricating oil consumption is to vaporize the fuel better.

If there is any special defect in our cars, trucks and tractors, it is that we fail to prevent leakage from the carbureter to the exhaust. That means no leakage of air between the carbureter and the intake manifold; none between the intake manifold and the cylinder, or in the intake-valve guides; no leakage of the valves into the combustion-chamber; none past the rings and pistons; and, lastly, no leakage past the exhaust valves. When we accomplish this, the economy is remarkable.

CHAIRMAN CRANE:—During the war we started building an engine of 150 hp., running 4-hr. tests at about 1500 r.p.m. The engineering development department did much experimental work on the same engine with possibly 15 per cent higher compression, which gained a very considerable amount of horsepower. We were finally ordered to put that engine into production. The shop brought the engines out and put them on the test-stand and every engine failed, without exception. The pistons were blown by and often holes were blown through the top. They were aluminum pistons. We found that the piston and cylinder job that was tight enough for a 4.75 to 1 was not tight enough for a 5.35 to 1 compression ratio. The leakage and the heat that goes with it increase somewhere between the square and the cube of compression ratio and the explosion pressure which follows. The result was that the pistons were being overheated and the oil in the cylinders all broken down by the waves of heat. They found they could make the pistons tight, and when they made them tight there

(*Concluded on page* 254)

Variable Factors in Highway Design

By H. Eltinge Breed[1] Annual Meeting Paper

THERE are two factors in transportation, the vehicle and the road. When transportation falters, each factor blames the other; the roads fail because the vehicles punish them too hard; the vehicles are impeded because the roads will not sustain them. So recrimination rounds the vicious circle, and we end where we started, in worse temper. Self excuse and shifting of blame only block transportation. To solve the problem we must work together, recognizing our mutual dependence. It is to the interest of automotive engineers to design vehicles that will afford the maximum transportation facilities with the minimum wear upon the roads; it is equally to the interest of highway engineers to design roads that will give the maximum transportation service at a minimum cost both to themselves and to the vehicles that use them. When, together, we have achieved that end, we shall have provided this country with a really adequate system of highway transportation.

If prospective traffic, soil conditions, drainage, surfacing, maintenance and politics were definitely known quantities instead of algebraic unknowns of more or less intense degree, then our problem would be simple, you would proclaim the glory of our roads, and we should hail the latest Leviathan in motor trucks as an object of supreme affection. Those conditions are not constant, however; they are variable. We can measure them at present only by empirical generalizations; what has happened before under similar conditions will probably happen again. To apply that slippery gage so as to secure uniform success requires unusual experience and ability, and even then a cog slips occasionally. Neither ignorance on the engineer's part, nor carelessness or fraud in construction is the cause of many of the failures; the variable factors involved simply defied the best opinion and practice obtainable.

Type of Pavement

Of the six factors, or variable conditions that I have mentioned, I shall speak of four but very briefly. It is on the other two, the first and last, that we can cooperate to secure better transportation service. In designing a road the first thing to be determined is the type of pavement to be laid. Although cost, soil conditions, availability of materials and other considerations influence the decision, the real factor that determines it is the volume and character of the traffic which will use the road. Because this traffic is problematical, the choice of pavement must be empirical rather than strictly scientific. We know that the heavy traffic around large cities demands the strongest and best types of pavement, and that in sparsely settled, non-industrial regions, we are safe in designing a semi-durable type, but in the whole wide field between these extremities, money, time and energy can be wasted either on over design at costs disproportionately high for the transportation service rendered, or on design that is so inadequate to the prospective traffic demands as to make failure inevitable. How can we design for this prospective traffic? We all perceive now the futility of the old traffic survey in helping us determine the type of pavement. Because only 10 motor cars travel today over the mud road between Alpha and Omega is no guarantee that only 100 motor cars will travel over it daily after the road has been improved. The problem is more complex: How much tonnage of all kinds, carried by all transportation agencies, is now consumed and produced daily by all the communities the road will serve? Then, how much of this tonnage is the motor truck able to haul? For it is fair to assume that, once the road is improved, all that can be transported by motor truck will be. Last, what is the probable growth of the communities in question, according to the latest United States census, with the increase per capita in goods consumed and produced? Given this freight haulage, the actual passenger traffic over the road is a corollary of minor importance. Let us know the prospective freight tonnage for which we must design, and we shall have a much more definite basis than any we have today upon which to decide our type of pavement.

There is one way in which we can cooperate in securing and preserving adequate pavements. We are all fairly well agreed now that the greatest damage done to roads is by impact, that is by the pounding of the load upon the road. This pounding is accentuated by any unevenness in the road itself or in the tire of the vehicle. There is the rise, the jolt, the drop of many tons weight upon the same spot over and over again and the gradual, inevitable shattering of the pavement, a little more at each blow. Many studies are being made about impact which will help us in the design of our roads, but this much we all know now from experience; a perfectly smooth tire on a perfectly smooth road affords no impact. It does not pound; it rolls, and the only wear is the negligible attrition caused by a smoothly rolling load.

We are trying to perfect a durable, firm pavement whose surface shall be as smooth, though not as slippery, as a starched shirt front. Can we, as highway engineers, depend upon the automotive engineer for the tires? Part of the tire trouble, we know, is due to the carelessness of motor-truck users and must be overcome by education in which we can both take a part; the automotive engineer for the preservation of the trucks and the highway engineer for the preservation of the roads. These are the significant facts about the relation of tires to roads; the smoother the tire, the less the damage from impact; the broader the tire, the more diffused is the weight of the load over the bearing power of the road. We ask your help in respect to smooth, broad tires and in the other matter of educating motor-truck users. The man who overloads his truck beyond its capacity is a public nuisance, and a renegade to your interests and ours. We cannot flay him, so he must be taught to keep within bounds.

Foundation, Drainage, Surfacing and Maintenance

Other variable factors in highway design which are perhaps so technical as to be of especial interest only to highway engineers are foundation and drainage. Briefly put, our problem is this; the stability of the soil determines the strength of the foundation we must use. This stability varies inversely with the moisture content, the more moisture the less stability, and consequently the greater strength of foundation required. How can we

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determine accurately the moisture content? We cannot! At present there is no definite gage by which to measure it. It varies according to the geological formation, the character of the soil and the season of the year. We only know approximately, from an examination of the roadway under discussion in the light of former experience with similar roads, just what strength of foundation will be necessary to sustain a pavement permanently. We can only estimate what drainage is necessary to take care of an unknown amount of water. Even on the same road, the design for the foundation should, I believe, vary if at one or more places the moisture content at the driest season is greater than it is in other places at the wettest season. It is economy to put the stronger and more costly foundation in the moisture-laden sections, and to build the lighter and cheaper foundation where the dryness gives a stability of soil that precludes a breakdown. The same principles apply to drainage, but in the final analysis, questions of foundation and drainage are answered by the personal opinion of the engineer, and upon him, at this point, depends the fate of the road and of the taxpayers' money. The investigations now being conducted about foundations will, I hope, afford us a more scientific basis for procedure.

Two other variables that affect our transportation system are surfacing and maintenance. The latter, largely beyond the power of the designing engineer, connects directly with the last point I should like to make, the effect upon our highway systems of political changes.

The variability in surfacing is apparent to the casual observer. Two pieces of pavement are built according to the same specifications, contiguous to each other, under exactly the same soil and climatic conditions. Yet one of those pieces is 90 per cent good; the other 50 per cent bad. The difference lies in the variation in human nature; one contractor uses scrupulous care in the selection of materials, safeguards the blunders to which the workmen are liable and himself supervises the proportioning, mixing, placing and finishing of the pavement. The other contractor shirks personal supervision, is lax in inspection of materials and depends upon lazy, indifferent or incompetent workmen. Ultimately, the former succeeds and the latter fails, but not before he has squandered our money and inflicted upon us miles of bad pavement. It is, of course, the function of engineering supervision to safeguard the public from the incompetent contractor, but although good supervision will prevent the most flagrant blunders or frauds, it cannot wholly offset the weak contractor's tendency to produce poor work.

Politics in the Highway Department

Back of much construction work lies the second main point on which I believe automotive interests and highway engineers might effectively cooperate. I refer to the political domination of highway construction and maintenance. Having been part of the highway system in New York State for 13 years, and having been out of it a sufficient time to place what I say beyond any suspicion of personal prejudice, I do condemn, in the strongest terms, the custom of making the development of our highway systems depend upon the turn of the political wheel. To develop the highway systems in the various States requires men at the head of each highway department whose tenure of office is secure; who are expert engineers knowing highways from the sub-base up and beyond; who care not one whit for political preferment, nor are in one whit dependent upon it; whose sole interest it is to do the work assigned to them and thereby give this country the basis for a transportation system that shall be a pride to the builders of roads, the builders of vehicles and the users of both.

As it is now, with every change of political administration, which occurs every two or four years, there is a change in the personnel of the highway department. New men come into power, men often entirely inexperienced in highway work. A shopkeeper, whose wildest reckonings have been in terms of thousands is suddenly called upon to control the expenditure of millions. Is it any wonder that he falters and is easily imposed upon? Or that his subordinates spend months in discovering what their jobs require, months more in learning how to do them and the remaining months in preparing what to try next, after they are ousted?

The evils of the system are apparent; lack of adhesion to any coherent, continuous plan; lack of a sense of responsibility beyond the glimmering hope that there will be as little graft as possible, and that that little will escape the attention of the opposite party; the apportioning of jobs and even the locating of roads at the dictation of political potentates and the passing of snap judgments on insufficient knowledge about important policies.

Generalizations are easier than a detailed study of cases. Hence if the outgoing incumbents have held that to please the public one must build many miles of road, no matter what kind, then it is highly probable that the incoming incumbents, moved by the storm of public protest against the premature disintegration of new-born roadlings will say, "We build for permanence; fewer miles, but better." So we get a patchwork of extensive poor roads and of limited good ones imposed and usually without discrimination about the needs of the special locality they are to serve.

Happily, there is even in this politics ridden era a type of commission that tries to apportion its money to best advantage, with the durable, more costly roads where they are most needed, and the cheaper, less durable types where the traffic is scant. But when one sees a fine brick pavement that would be a credit to a town, built where it leads nowhere, one becomes depressed. We need completed systems, not costly spurs.

There is no reason why roads should be dominated by politics. If influential bodies like this Society would combine to rouse public opinion, changes could be made in the highway laws that would permit the securing and retaining of competent men, preferably experienced highway engineers, in charge of the work. Then through the control of these first and last variable factors we might hope to accomplish speedily and economically our mutual purpose of giving this country, large as it is, the best transportation system in the world.

The Packard Fuelizer

By L. M. Woolson[1]

Cleveland-Detroit Sections Paper *Illustrated with* Photographs and Diagrams

To present in the proper light what the Packard fuelizer is and how it performs its functions, it is advisable to consider briefly what the general requirements are for ideal carburetion under varying conditions. Let us consider first the basic engine such as is shown in Fig. 1. There are three main elements of the design with which we are concerned; the carbureter or fuel-metering device, the manifold, and the combustion-chamber. Each of these elements has its particular functions to perform. The carbureter must furnish a suitable mixture over a wide range of speeds and loads; the manifold must distribute this mixture in a suitable condition and in a uniform manner to the various cylinders, and the combustion-chamber must permit complete combustion of the fuel. None of these elements can perform the functions of another; if the carbureter does not produce the desired mixture the manifold cannot deliver it to the cylinders, and if the manifold does not de'iver a uniform mixture to the different cylinders, conditions in the combustion-chambers naturally will vary.

Considering the carbureter first, this has been developed gradually to a point where reasonably good operation is assured, and the metering characteristics are sufficiently accurate for practical purposes over a wide range of conditions. The average carbureter, if properly adjusted, will deliver a 15 to 1 substantially constant mixture, or whatever may be desired, under all ordinary running conditions. There is much work to be done in making the carbureter produce the varying mixtures actually required for the most efficient operation of the engine under varying conditions. However, at present we are concerned with the supply of a mixture of air and gasoline maintained at practically a constant ratio under varying load and speed, and in this respect the modern carbureter can be considered satisfactory.

It must be admitted that manifold design has been largely a matter of trial and error. There are a few well established rules to follow but, in general, we build the manifold first and fit a theory to it afterward. Almost any design of manifold will deliver a mixture of gases in a very uniform manner to the several cylinders, but when we attempt to distribute a mixture of air and liquid gasoline particles we find it extremely difficult to obtain uniform distribution. The gasoline particles can be considered as occupying the relative space shown in Fig. 2. Their volume is only 0.01 per cent of the volume of the air in the manifold. Furthermore, their weight for a given volume is about 560 times the weight of the same volume of air, with a correspondingly greater inertia. Therefore, it is not surprising to find that, if the gasoline is in the manifold in a liquid state, uniform distribution is practically impossible. Gasoline is not an homogeneous substance with a fixed boiling point, but is of a very complex nature and various fractions of it boil at various temperatures. Furthermore, the fuel will be broken up mechanically to a greater or less extent, dependent upon the jet construction and the atomizing means, if any, which may be employed; so, the manifold is called upon to distribute a mixture of gasoline and air which has practically the same chemical composition for all carbureters. The physical structure of this mixture depends, however, upon several variables; but, in general, the mixture, as delivered by the carbureter to the manifold, is at best merely a spray of liquid gasoline mingling with the air current.

We find a great variety of designs of combustion-chamber, dependent largely upon the valve arrangement; the L-head, T-head, overhead and F-head arrangements, each of which produces a combustion-chamber with a certain characteristic shape. The behavior of the mixture of gasoline and air after entering the cylinder is determined to a certain extent by the shape and design of the combustion-chamber. Generally speaking, however, the troubles which the fuelizer was designed to overcome are common to all forms of combustion-chamber. There is, however, much to be done in combustion-chamber design to eliminate or diminish detonation, which in itself represents a large field for study. This point serves to bring out again that each of the three elements of the engine which we are considering has its own problems. Detonation is largely a matter of combustion-chamber conditions and is related only indirectly to manifold conditions.

Uniform Distribution

It is difficult to secure uniform distribution with what we term a wet mixture. There are two other main reasons why wet mixtures are undesirable, especially when the engine is working on part throttle under reduced load, as is the case in automobile practice fully 90 per cent of the time. First, spark-plug fouling has been found to be brought about almost exclusively by wet-mixture conditions. It has been shown that an excess of lubricating oil in the combustion-chamber is not responsible for fouled spark-plugs, as was commonly thought. In fact, if an engine is supplied with a dry mixture, the spark-plugs will continue to function in spite of an excess of clean oil that may be present. We hear often that some engines pump oil in certain cylinders and foul spark-plugs by so doing but, as a matter of fact, experiments have shown that this is merely a mixture condition associated with poor distribution. It is the end cylinders of an engine that will be said to pump oil and foul spark-plugs as a general rule. The reason is that, in nearly all manifold designs, there is a tendency for the heavy gasoline particles to continue in a straight line to the end of the manifold. There they turn in and thus bring about these spark-plug fouling conditions. There is also the problem of the dilution of the lubricating oil by so-called kerosene, which is a familiar condition. This has been considered formerly as a cold-weather condition only, but many cars are bad offenders in this respect in even moderately warm weather. I believe that these facts are

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recognized universally at present and that the desirability of a dry mixture, at least for part-throttle work, is self-evident.

Many methods of supplying the requisite amount of heat to the intake manifold have been tried. The use of heat from the exhaust gases has been favored recently, and many schemes have been evolved with the idea of concentrating the heat where it will do the most good. I will not attempt to discuss these various devices in detail but will state that the fuelizer was evolved only after several different types of exhaust-heated manifold had been tested and found wanting in some particular or other. The trouble was not that there was insufficient heat available in the exhaust, since the exhaust may contain from 25 to 50 per cent of the heat units obtainable from the original fuel. As a matter of fact, considerably less than 5 per cent of the heat contained in the fuel which the engine is using is required for vaporizing purposes. The main point has been that the exhaust heat is represented by a comparatively large volume of gas at a comparatively low temperature, and what is required for the efficient application of heat to an intake manifold is rather a limited amount of gases at very high temperatures.

Another reason for this latter requirement is that it involves a very simple means of regulating the heat in accordance with the work the engine is performing. As is well known, the volumetric efficiency of an engine is dependent upon the weight of the charge drawn in, and it is obvious that if we heat the charge it will expand. A given volume of the heated charge will weigh less than the same volume of cool charge; consequently the output of the engine will be decreased in proportion to the temperature rise of the mixture. The extent of this loss in volumetric efficiency can be judged when we consider that for each fahrenheit degree rise in temperature there is a loss in weight for a given volume of about 0.2 per cent, so an increase of say 100 deg. fahr. would mean a loss in output of something like 20 per cent.

Detonation

There is another serious disadvantage in maintaining the mixture at too high a temperature under wide-open-throttle work. This is in connection with the phenomenon of detonation, which has been recognized only lately to be the cause of what is familiarly termed "spark knocking" or "spark hammering." When a charge is ignited in the combustion-chamber, the flame propagates in all directions from the point of ignition and, if the engine is working on full throttle, it may happen that some of the charge will be so highly compressed by the advancing wave of flame that it will detonate. The momentary pressure due to detonation may be three or four times as great as the pressures brought about by more gradual combustion. There are many factors influencing detonation; the general shape of the combustion-chamber, the location of the spark-plug, the compression ratio, the extent and thickness of the carbon deposit upon the combustion-chamber walls and piston-head, the temperature of the jacket water and temperature of the incoming charge. It will be seen readily that if the temperature of the incoming charge is greater, a proportionately larger amount of highly-compressed unburnt-mixture will detonate.

The theory has been advanced that, within reason, the higher the temperature of the incoming mixture is, the better the fuel efficiency under wide-open-throttle conditions will be. However, this has not been borne out in practice. The Bureau of Standards has confirmed this

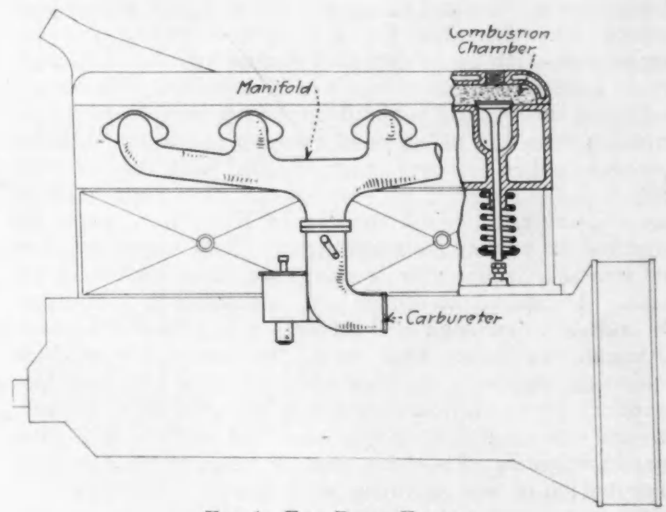

Fig. 1—The Basic Engine

by recent tests which show that, when running wide-open, there is very little if any connection between fuel economy and mixture temperature. In the matter of acceleration, however, a paradoxical condition prevails. Although we have seen that volumetric efficiency falls off with increase of mixture temperature, it is true that the accelerating quality of an engine is very much improved by an increase in mixture temperature. This also has been confirmed by some recent Bureau of Standards' tests. I have driven cars with mixture temperatures exceeding 400 deg. fahr. which had extremely good acceleration. However, when a hard steady pull up a steep grade or through heavy going is required, a cool mixture gives by far the best results, owing to the improved volumetric efficiency. Incidentally, there seems to be no disadvantage in using relatively cool mixtures under wide-open-throttle conditions. This is no doubt due partly to the high temperatures prevailing in the combustion-chamber and on the piston-head and, as is well known, spark-plug fouling and crankcase dilution are not ordinarily associated with wide-open-throttle work. Accordingly, we find that the following rules apply as to the most desirable mixture temperatures to be maintained:

(1) For idling, fairly high temperatures are to be attained as quickly as possible after starting, to avoid loading, spark-plug fouling and crankcase dilution
(2) For slow running on part throttle, an equally high temperature is desired. Very good results for this work are given by a temperature of 180 deg. fahr.
(3) For accelerating, a similarly high temperature is desirable
(4) For continuous wide-open-throttle work, the lower the temperature is, the greater the power will be; although a mixture temperature below 100 deg. fahr. with present-day gasoline is not advocated. This is merely a concession to good distribution

As to why distribution under wide-open-throttle condi-

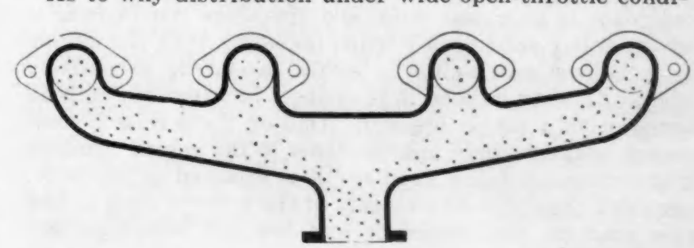
Fig. 2—Diagram Showing Mixture Conditions in the Manifold

tions does not demand an equally dry mixture, as has been stated was desirable for low-throttle work, practical experience with many types of engine has shown that in every case good distribution can be obtained with proper manifold design and without supplying more heat to the mixture than can be supplied through the water-jacketed passages which are commonly integral with the cylinder. This is substantiated by fuel-consumption tests such as were conducted by the Bureau of Standards, with the mixture at various temperatures. This condition does not necessarily apply to lower-grade fuels such as kerosene. I believe we have an insufficiently thorough theoretical knowledge of distribution to prove this point, although we know that with the increased mixture velocities met with in wide-open running there is less tendency for the liquid particles to separate from the air-stream and condense on the manifold walls. It is this condensation or deposition that is responsible for poor distribution of wet mixtures with low mixture-velocities. Then again, under a wide-open-throttle condition, the increased compression pressures, the higher temperatures of the combustion-chamber walls and the increased turbulence all assist in carrying out the combustion of a wider range of mixtures than would ignite under less favorable conditions.

Ignition

The source of the ignition spark for the fuelizer is an important element in the device. There are several different ways of securing the necessary current but, as a result of experience, certain methods have proved the most desirable. With battery-ignition systems, a separate low-tension breaker can be used in conjunction with a standard ignition coil. The secondary winding is connected directly to the fuelizer spark-plug. This plug is of special construction only in the electrode arrangement. A wide gap has proved to give the best results, the gap used being about 1/8 in. It has been found also that the amount of spark heat is of considerable importance, especially when starting up in extremely cold weather. In this respect the requirements are very similar to those demanded of the engine ignition system and, in general, the same type of coil windings can be used for both engine and fuelizer ignition service. If it were desirable to limit the current consumption to a minimum, a special coil having many more primary turns could be built for the fuelizer. The increased self-induction would result in a poorer spark at high speed, but this would not affect the fuelizer operation materially, since its main purpose is to supply heat at the lower speeds. Another method of securing the fuelizer spark consists of bringing out the inner end of the secondary winding of the regular ignition coil. Normally, this terminal is connected to ground either directly or through the primary winding. It is believed that such a method does not represent good practice, since the wide gap of the fuelizer plug offers considerable resistance when the throttle is wide-open. Under these conditions the compression pressure in the cylinders is at a maximum and therefore the resistance of the entire secondary circuit, including both the engine and fuelizer spark-plug in series, would be excessively high. Another method is to connect two ignition coils in series with a single breaker. One of these coils is connected to the fuelizer and the other to the engine ignition distributor. A fairly good result is attained in this way, provided the different elements of the system, such as the cam contour, the condenser and the coil windings, are suitably proportioned.

When magneto ignition is used, a special magneto is required. For four-cylinder installations, several types of five-spark magneto are available. In one type the rotor and interrupter are of eight-cylinder design, four sparks per revolution of the rotor being produced. Two of these go to the engine spark-plugs and two to those of the fuelizer. This system permits using only the negative sparks for engine ignition, which has certain advantages from the standpoint of spark-plug-electrode life. Another means of obtaining a magneto spark for the fuelizer is insulating both ends of the secondary winding, which is commonly done in two-spark magneto construction.

Generally speaking, the requirements for the fuelizer ignition are similar to those for regular ignition. It is of advantage to have not less than two fuelizer sparks per revolution of the engine to assist in starting. Once the flame is established it will continue without the aid of a spark until such time as the throttle is suddenly opened. However, in practice it does not seem worth while to cut off the spark while the engine is running, although it is obvious that a simple thermostatic control could be worked out for this purpose. The spark-plug is of conventional construction except for the electrode, and this can be constructed in any manner desired without the restrictions imposed by preignition on regulation spark-plug design.

The Fuelizer vs. Hot-Spots

The question may arise as to the comparative merits of the hot-spot and the fuelizer. By hot-spot I mean any of the exhaust-heated manifold-designs in which the heat is more or less localized. I believe the best answer is that the fuelizer covers a wider range of actual service, but that the fuelizer in conjunction with a judicious use of additional heat from either the exhaust or a suitable water-jacket offers the best solution. The average exhaust-heated manifold warms up quickly if the throttle is opened when starting off; that is, if the engine is raced or if the car is run in low gear for a short distance. The fuelizer, on the other hand, operates to the best advantage when the engine is idling or operating under a reduced load. Under ordinary driving conditions the rate of mixture-temperature increase will be very much more rapid with the fuelizer. In exceptional cases, such as starting off cold at the base of a long hill, the exhaust-heated job may have the advantage, since this wide-open-throttle condition automatically cuts down the action of the fuelizer. A combination of these two systems covers every conceivable driving condition. Of course, as pointed out elsewhere, the application of the exhaust heat must be carried out carefully so as not to reduce the volumetric efficiency of the engine under wide-open throttle. In actual practice a suitably designed water-jacketed manifold gives excellent results in conjunction with a fuelizer, and this is of particular advantage in engine designs in which the intake manifold is on the side opposite from the exhaust manifold. Another point in favor of the fuelizer is that its design requires the least amount of metal exposed to a high temperature. When driving requirements change suddenly from light load to full load or vice versa, a suitable mixture temperature is arrived at very much more quickly with the fuelizer than with any exhaust-heated system. With this latter construction there is necessarily a greater mass of metal to cool off or heat up than with the fuelizer, and the time required to arrive at the desired temperature is necessarily prolonged.

The all-important advantage of the fuelizer over any exhaust-heated system is that it supplies the heat in exactly the amount needed to meet average driving condition. If an exhaust-heated manifold is made to give the mixture anything like the heat demanded for good idling and slow-speed work in cold weather, it will heat the charge unduly on a stiff pull on a hot day. This will result in a decreased power output of the engine and also an increase in heat loss to the jacket water which in turn requires great heat-dissipating ability on the part of the radiator.

What the fuelizer accomplishes under various conditions of operation is summarized as follows:

(1) In starting, it generally comes into operation even before the engine starts firing; this is especially noticeable in severely cold weather. The fuelizer is therefore of real service in insuring a prompt start

(2) For warming up, if the engine is allowed to idle for a few moments the fuelizer heats the manifold very quickly. Even in severe weather, when driving away immediately after starting up, the engine will fire regularly within a very short distance

(3) For hard pulling, dynamometer tests show absolutely no difference in power when running wide-open with the fuelizer connected or disconnected. It is obvious that, since no heat is supplied by the fuelizer under these conditions, there can be no loss in volumetric efficiency

I have endeavored to show that the fuelizer furnishes the proper amount of heat to the intake manifold under all conditions of running. This is accomplished in a very simple manner, particularly in some of the later designs, demanding practically no added complication to the engine except an extra source of ignition current which can be synchronized with the regular ignition current so as to form, if desired, a reserve system of engine ignition for emergency.

The Detroit Discussion

U. G. Thomas:—How much gasoline does this fuelizer save?

L. M. Woolson:—That depends upon the driver. Recent tests show that if the fuelizer is operated to the best advantage and the mixture is made suitably lean, a substantial increase in gasoline mileage should be attained. It is difficult to persuade drivers to pay any attention to carbureter adjustment, assuming that there is some kind of dash adjustment. The average driver will pull out the choke to start and probably leave it in that position unless something happens to call his attention to it. In certain cars weighing about 3400 lb. we have consistently obtained 21 miles per gal. of gasoline with the fuelizer. We might obtain just as good or better mileage without the fuelizer in warm weather, the figure I have given refers to average driving mostly in winter. The advantage of the fuelizer is that it enables the engine to run with the leanest possible mixture. If the driver does not take advantage of this, it is of course of no avail. I hope we shall have carbureters that require no attention from the driver, these being controlled thermostatically or automatically in some other way. With such carbureters we could get increased mileages. On a certain car equipped with the fuelizer, the test results were 15.6 miles per gal. when running without the fuelizer, and 15.3 miles per gal. when running with it. The carbureter adjustment was the same in both cases. When running with a fuelizer, a much leaner mixture can be used; it is

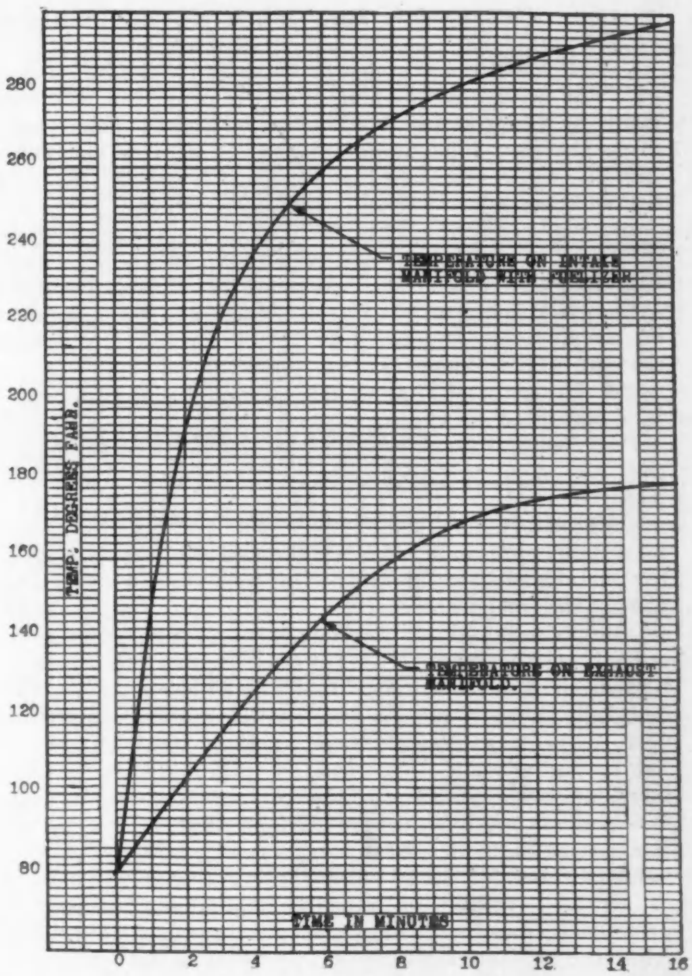

Fig. 3—Curves Showing the Increase in Temperature on the Outside of an Intake Manifold Equipped with the Fuelizer Over That on the Outside of the Exhaust Manifold

difficult to state off-hand how much gasoline that would save. I believe that if the mixture were made lean as soon as the fuelizer began its action, at least 15 per cent of the gasoline could be saved.

H. S. Benjamin:—Fig. 3 shows a rise in temperature of the intake manifold and the exhaust, and that the intake had a more rapid rise in temperature than the exhaust. If the exhaust manifold could be made of aluminum, what would be the comparison in the rise in temperatures?

Mr. Woolson:—It would be far more favorable, but the ultimate temperature for idling would be very much greater in any case. We have measured temperatures on the fuelizer jacket walls of 800 deg. fahr. after a few minutes of idling; for instance, at the spreader of the V-type installation. The exhaust pipe never reaches any such temperature except when running with fairly wide-open throttle.

Mr. Benjamin:—What is the temperature inside of the intake manifold during idling?

Mr. Woolson:—It will vary. With a water-jacket it probably will never go much beyond 220 deg. fahr. because the heat conductivity of the water prevents further temperature rise. In the single-six installation the temperature will go very much higher under prolonged idling because the apparatus is bolted directly to the exhaust pipe and the intake passages are formed partly integrally; probably 330 deg. fahr. would be reached in time.

Mr. Benjamin:—Do you not find that the heaviest

portions of some motor fuels do not vaporize uniformly at 450 deg. fahr.?

MR. WOOLSON:—We should not confuse the end-points of fuels with the temperatures required for effecting complete vaporization in a 15 to 1 mixture. Under sub-atmospheric conditions as obtained in a manifold, nothing like a 450-deg.-fahr. temperature is needed to get a dry mixture.

MR. BENJAMIN:—That is true. I had crankcase dilution in mind. A certain part of the fuel will get past the piston-rings and cause dilution. If the temperature in the manifold is about 280 deg. fahr. and the end-point of the fuel is 450 deg. fahr., there will be a certain amount of crankcase dilution.

MR. WOOLSON:—That would occur only if the fuel were in a saturated atmosphere.

PROF. O. C. BERRY:—Tests at Purdue University show that Mr. Woolson's point is correct. We use a piece of metal about 3 in. wide, 10 in. long and 3/4 in. thick, with a slight depression in the top. Fuel is syphoned over into that depression. There is a heating element under the metal and holes are drilled alongside the depression, so that the temperature of the metal to which the gasoline or fuel is exposed can be determined. The results reported are the number of minutes required to vaporize 0.01 lb. of fuel from 1 sq. in. of heated surface. At 300 deg. fahr., about 7 min. is required to vaporize completely 0.01 lb. of Red Crown power gasoline on 1 sq. in. of heated surface and this grade of gasoline has an end-point of 450 deg. fahr. The correct mixture, as Mr. Woolson stated, has just enough gasoline to use up all the oxygen at 15 lb. of air for 1 lb. of gasoline. With a value of three for the gasoline vapor, we have 45 volumes of air to 1 volume of gasoline vapor; so, the partial pressure on gasoline is only 1/45 of atmospheric pressure. Although the temperature of this room is less than 212 deg. fahr., the boiling temperature of water, the water vapor in the room would create a pressure of something like 1/2 in. of mercury; that is, it is possible to have the vapor present in the atmosphere at a lower temperature than corresponds with the boiling point of the liquid. We had a clean dried-off surface at a temperature considerably less than that of the end-point of the fuel for that reason.

T. J. LITLE, JR.:—When using a rather lean mixture, did not the flame retreat into the interstices of the gauze at the upper part of the fuelizer and burn it? We experienced that trouble in the development of Welsbach-light burners, particularly with pressures such as occur in burning gasoline, kerosene, distillates, alcohol and the like. What is the extent of dilution incidental to the introduction of that much burned charge directly into the intake manifold?

MR. WOOLSON:—We originally used a 40-mesh screen. A lean mixture would burn a hole, frequently within 400 to 500 hr. But with the mesh we are now using, the heat conductivity of the aluminum body of the burner is sufficiently great to prevent any such action, no matter how lean the mixture is. We have run these for 2000 hr. and none of the screen was consumed. Regarding the effect of the dilution caused by the burned gases, there is a strange phenomenon that many people do not recognize. There is absolutely no effect that is noticeable to the driver. There is about a 10-per cent dilution at very slow speed, but the engine can be idled at a slower speed with the fuelizer than without it. In the Van Blerck installation, it is almost impossible to stall the engine. As a matter of fact, at 1/2 m.p.h. there is no noticeable effect as regards dilution; the idling is not affected. The only evidence of the presence of the dilution would appear upon disconnecting the fuelizer and letting the mixture that was burning in the fuelizer join the main mixture. In that case the engine would speed up slightly, because it would be getting slightly more mixture than before.

MR. LITLE:—My understanding is that the charge from the burner enters the intake manifold through small orifices. Do small projections of flame enter the screen and cause back-firing?

MR. WOOLSON:—We feared much trouble from this but have had none. The orifices must be far enough away from the burner body and the gases must be made to take a circuitous path if necessary. On an installation like that on the V-type engine, we use 3/16 in. diameter orifices. We have never experienced back-firing, but if the openings were increased to 1/4-in. diameter there would be occasional back-firing.

PROF. BERRY:—It seems that in starting an engine in cold weather with the present grade of gasoline, if the temperature is too low, not enough gasoline is vaporized to support combustion and it is almost impossible to get ignition in the cylinder. Is the temperature below which we cannot go very much lower with the fuelizer than without it?

MR. WOOLSON:—The lowest temperature at which I have experimented with this device is about 10 deg. below zero fahr. We obtained very prompt ignition in the fuelizer burner body. We found we had ample heat in the spark there; it is only a matter of obtaining enough heat to start.

J. H. HUNT:—There is no such thing as a critical temperature, but the problem becomes progressively difficult. I think it is not caused entirely by the condition of the gasoline; I think the trouble is in getting the fuel to the place where we want it. The cranking speed is reduced greatly. Is there any specific figure for the amount of fuel that should be consumed in the burner, as compared with the amount of fuel that the engine is using when idling? Is there a ratio that could be applied, in going from one design of engine to another?

MR. WOOLSON:—That can be computed mathematically from the specific and latent heats. I believe a desirable increase of mixture temperature is something like 100 deg. fahr. To raise the temperature of the air and that of the fuel 100 deg., and completely vaporize the latter, something like 2 per cent of the British thermal units of the fuel dealt with must be consumed in the burner. The efficiency of the proceeding is fairly high. It is a kind of self-contained boiler proposition. It operates at something like 90 per cent fuel efficiency; so, it is simply a matter of what condition it is desired to meet. In arriving at the various calibrations we used common sense, not trying to go to extremes. We did not endeavor to melt the manifold, although that can be done. On an engine of about 400 cu. in. displacement, certainly not more than 1/2 pint per hr. should be burned at any time.

MR. HUNT:—What I referred to is more a matter of experiment than mathematics, because it is very certain that we want to use more than 2 per cent of the fuel that the engine requires when idling. We are not satisfied with simply a 100-deg.-fahr. rise to get a quick result.

MR. WOOLSON:—That is all a matter of the standard set. A 100-deg.-fahr. rise is considerable. It might not do for extreme conditions, but when we build apparatus like this, we try to meet average conditions. In connection with this fuelizer we try to make it as simple as possible; no matter how simple it is there is enough

cause for trouble. If enough heat were used to serve at 30 deg. below zero fahr., certainly some control would be needed to shut it off in summer, which would involve complication. By adopting a middle course, giving sufficient heat for the average result, we satisfy everybody, I believe, and avoid creating too high a temperature in summer. The device permits, however, the use of as much gasoline as one cares to burn. I have never found any limitations.

MR. LITLE:—Is not the greatest value of this fuelizer the heating of the manifold quickly? That is its greatest function, I should say. With a cold engine in winter one gets under way very quickly.

MR. WOOLSON:—Yes.

MR. LITLE:—Instead of burning ½ pint per hr., why not burn 1 qt. per hr., and then cut it off? Would it not be desirable to get under way more quickly?

MR. WOOLSON:—That would mean some sort of manual control. We wanted to avoid that. The average car is used for fairly short hauls in winter. The opportunity for cutting the fuel supply off would probably not present itself very often on a cold winter day. It would not be desirable to cut it off for 2½ or 3 miles. I question whether it would be worth while to make provision for the occasional driver. The device is actuated very easily by opening the ignition circuit, although the throttle has to be stepped on to extinguish the flame. Opening the ignition circuit would form a certain and practical way of controlling the action.

MR. BENJAMIN:—Is not the apparatus arranged to shut off at a certain intake temperature?

MR. WOOLSON:—It does not respond to temperature influences, but only to depression influences.

MR. BENJAMIN:—But as the throttle is opened the temperatures increase and the fuelizer shuts off.

MR. WOOLSON:—That is a fortunate incident. As the throttle is opened, no more heat is needed and, as the compression pressure increases and the amount of suction decreases, less mixture is pulled through the fuelizer and less is burned. Consequently, the heat decreases; but the response is to manifold depression only, and not to any other influence.

A MEMBER:—Fig. 4 shows that there are two sources of heat. The incoming gas receives heat from the exhaust jacket on one side of the fuelizer; the other source is the exhaust gases from the fuelizer that enter the manifold itself. Which source is considered the more beneficial?

MR. WOOLSON:—The benefit from one source equals that from the other. When starting cold the direct contact of the heated gases of the mixture undoubtedly helps for the first few seconds. On the other hand, when accelerating, it is very desirable for best results to have very high mixture temperatures. The heat that is stored in the metal comprising the fuelizer body is then relied upon. At low mixture-velocities the gasoline tends to hug the walls, deposit on them and creep up slowly. By having the walls hot, that effect is prevented.

A MEMBER:—What is the temperature of the gases that come in through the orifices in the fuelizer body itself?

MR. WOOLSON:—I cannot give accurate information regarding that. The temperature in the burner body is about 1000 deg. fahr. and where the burned gases in entering join the main gases they may have dropped 200 to 300 deg. fahr. during their passage. That is a fairly accurate statement. We have never put on thermocouples, because we thought that this was not necessary.

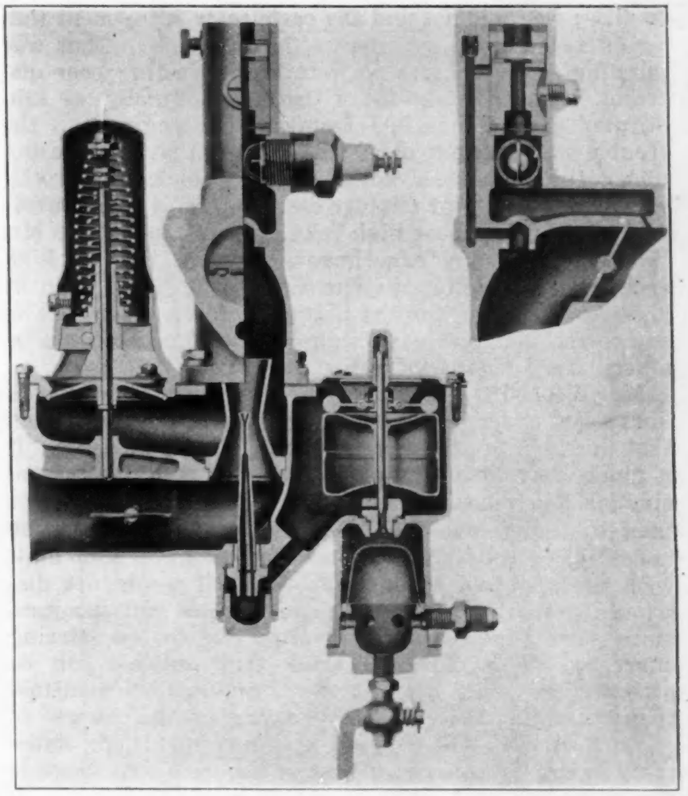

FIG. 4—AN APPLICATION OF THE LATEST TYPE OF FUELIZER TO A SIX-CYLINDER PASSENGER CAR

MR. HUNT:—The temperature of those gases is well over 2000 deg. fahr.

MR. WOOLSON:—When using aluminum bodies? How is that?

MR. HUNT:—The gases are cooled by the mixture on one side, or the device would not be possible. I refer to the flame immediately below the plug. The theoretical temperature, assuming that the specific heat of the air remains constant, is well up to 3000 deg. fahr.; we know it is above 2000 deg. fahr. until after it has been chilled, for we have actually measured the temperature of the flame.

MR. WOOLSON:—As a rule we use a cooler mixture that is somewhat too rich. We do that to get quick starting. A perfect flame would be colorless or very light blue and extremely hot. The flame we generally use is somewhat greenish in color. It probably contains a considerable amount of carbon monoxide. When running with a very lean mixture the heated electrode becomes red-hot, but not when running in the usual way.

MR. HUNT:—The pipe on your demonstration outfit is bright red. The temperature of the plug does not show the temperature of the flame.

MR. WOOLSON:—Not altogether. The point of maximum heat is determined by the richness of the mixture. A lean mixture will tend to burn up near the top of the flame. The rich mixture will tend to burn further down.

PROF. BERRY:—The statement has been made that the fuelizer is not so necessary for wide-open-throttle running as for starting up. As I understand it, the assumption is that under wide-open-throttle conditions there is better distribution through the manifold. I observed an engine under test conditions that did not seem to confirm this. It idled well and under throttled conditions at almost any speed seemed to give very good performance. But at high speed and wide-open throttle, it continued

to miss; we could not find any carbureter adjustment that would cause every cylinder to fire regularly. That was puzzling to us, because we were not expecting poor distribution under conditions of that kind. Finally, we substituted a good manifold from another engine and the trouble was eliminated. I am satisfied that the missing under the high-speed conditions of wide-open throttle was due to very poor mixture distribution in a cold manifold, even under those high-velocity conditions. Has Mr. Woolson made any experiments showing that at high speed there is better distribution of the liquid than at low speed, or whether the better engine performance is due to the fact that with high compression there can be a very much more poorly mixed charge?

MR. WOOLSON:—I qualified my statement that heat is not needed under wide-open throttle conditions, by stating that this applies only with a suitable manifold design. It is much easier to design a manifold that will give reasonably good distribution under wide-open throttle conditions than to design one that will give perfect distribution under idling conditions. Some engines have been built with the manifold so unsuitable that it would not distribute properly. Some airplane engines will generate more power under partial throttle, due to the stirring effect on the mixture. I think that problem can be attacked very much better by designing another manifold than by stifling the engine by heating up the charge.

PROF. BERRY:—Even with the best manifold, something is lost by cutting off heat at the wide-open throttle conditions.

MR. WOOLSON:—If that were the case, it would surely appear in the economy runs made at various temperatures. We ran a great many, with temperatures ranging from 90 to 212 deg. fahr.

PROF. BERRY:—Was that while using aviation gasoline?

MR. WOOLSON:—Yes, but aviation gasoline at 90 deg. fahr. is not very tractable; the fuel efficiency in pounds per horsepower-hour shows as nearly a flat line under those conditions. If the distribution were assisted to any material degree by the heating, it would be reflected in better fuel economy, would it not?

PROF. BERRY:—I believe it would be.

MR. WOOLSON:—Another way of looking at the problem of supplying heat at wide-open throttle is to consider what is done when a certain size of engine is to be designed, such as one of 200 cu. in. That size is selected because it is thought to be the smallest that will develop 50 hp., but the only way 50 hp. can be obtained from that size of engine is by keeping the mixture fairly cool. If the mixture is kept heated, the size of the engine must be increased; so I see no point in adding heat. The kerosene engine is a different proposition.

CHAIRMAN EARL G. GUNN:—Everyone who has had anything to do with engine design has certainly experimented with the heating of intake-manifolds in some manner or other. What is the effect of the fuelizer on a smoky exhaust?

MR. WOOLSON:—On a cold day an engine not equipped with a fuelizer will emit considerable kerosene smoke if opened up after prolonged idling. The same engine equipped with a fuelizer can be idled indefinitely and will open up clean. Much of our experimenting was done in the summer. We built a box around the manifold and filled it with cracked ice and calcium chloride. It produced fairly good results. Mr. Hunt can drive a car into the laboratory refrigerator room for experimental purposes, and that is the ideal way.

MR. LITLE:—After the engine has been in the refrigerator room, say for 24 hr. at 10 deg. below zero fahr., within how many seconds will the engine start?

MR. WOOLSON:—We made a test at about 5 deg. above zero, which was as low as we could get at the time. That particular engine started within 8 sec. The fuelizer started almost instantly. The engine was able to run idling in the refrigerator room within 20 sec. with the summer setting on the air-valve.

MILTON TIBBETTS:—It appears to have been taken for granted that everyone knows what results have been given with the fuelizer as regards crankcase dilution and spark-plug fouling. What are the actual results along that line?

MR. WOOLSON:—I have never seen or heard of an engine on which a fuelizer was operating that ever fouled a spark-plug. That covers an experience of 18 months with several thousand cars. I believe that a spark-plug could not be fouled under ordinary driving conditions on a car equipped with a fuelizer; the porcelain might break, the electrodes might burn off, or something else might happen, but the spark-plug will never foul in the accepted sense of the word. As to what is achieved in regard to crankcase dilution, with the fuelizer in operation we do not maintain the viscosity of the oil at the original figure, because that is not necessary. But we keep the crankcase oil from building up in winter. The engine uses its regular amount of oil, and its viscosity is reduced somewhat in cold weather, but that does not matter. Not much dilution is required to reduce the viscosity slightly. One of the most needed accessories at present is some sort of simple viscosimeter. We tell the owner to test the oil, but he can do this only in a very crude way. Some efficient way of testing oil is required because much oil is wasted. Garages should be equipped to recover good oil from oil that is now thrown away. Many makers tell people to throw away the oil every 500 miles. That represents a considerable waste of the petroleum resources of the country; it must amount to several millions of gallons annually. Something ought to be done about it.

G. E. GODDARD:—Have you made any tests to show what percentage of gasoline the oil contains when running with and without the fuelizer?

MR. WOOLSON:—We generally make these tests with weighing apparatus. We made many oil-consumption tests with the fuelizer and without it. This can be done on the dynamometer very well. The oil supply increases at a definite rate when running without a fuelizer, due to dilution. If the fuelizer is kept in action and a dry or nearly dry condition maintained, the difference is something like 4 oz. per hr. under idling conditions, with the water temperature at about 100 deg. fahr. While crankcase dilution is not entirely eliminated with the fuelizer, it is eliminated to such an extent that it is no longer a problem.

A MEMBER:—Will the manufacturer build a fuelizer adaptable to almost any car having a manifold such as that on the Ford car, and that will tend to eliminate all trouble?

MR. WOOLSON:—We have tried the fuelizer on many different makes of car. There was not a case in which we did not get better results.

MR. TIBBETTS:—Mr. Woolson and I have worked together on that and the Packard company has tried to cooperate with other manufacturers in this matter of adapting the fuelizer to various cars, particularly the old ones. So far we have not been able to do that. I do

not know whether we ever will or not. It is a large problem.

THE CLEVELAND DISCUSSION

MR. WOOLSON:—Fig. 5 shows a cross-section of the fuelizer, which I will describe briefly. It has a conventional-type carbureter. The suction plugs are located above the throttle and have 3/16-in. holes. When the engine is running slowly there is a high suction that draws in a mixture of gasoline and air through the burner, where it is ignited. Heat is communicated to a portion of the manifold and the burned gases go down through the side walls. We thought we would encounter preignition. As a matter of fact, we observed flame coming out at these plugs and we had no difficulty with it at all. It was easy to cool the mixture and so prevent premature firing. The small carbureter is built in the simplest way. It is a difficult problem to carburet say from 0.1 to 0.3 pints of gasoline per hr. The annular spray is 1/64 in. The mixture issues from the small carbureter through an elbow which has a peculiar construction. It then goes through a screen and, passing a plug, is ignited. The ignition is continuous between closed and half-open throttle. The manifold is water-jacketed. That is in connection with the desirability of having some heat on wide-open throttle. As regards heat during acceleration, we get that by having plenty of metal directly under the flame. That provides the heat necessary while accelerating, and it cools off rapidly under a hard pull.

When starting up cold the air-valve spring is highly compressed and the choke which controls the air is almost entirely closed. We found that to start the fuelizer burning promptly a somewhat richer mixture was required until the burner heated up. That sounds simple enough but it bothered us for a long time. To make the mixture rich, we take the primary air of the small carbureter from the secondary air passage of the main carbureter. When we shut off the air from this passage, we also cut off the supply to the auxiliary carbureter. It then gives a richer mixture.

I have made many tests at low temperatures, such as 10 deg. below zero fahr. The fuelizer generally starts burning an appreciable time before the engine commences to run. In fact, it is easily conceivable that it is the heat supplied by the fuelizer that assists in the starting of the engine. In Fig. 3 it will be noted that the burned gas joins the main mixture at two places. Getting equal distribution of the burned gas presents a problem, but it is not a difficult one. We thought, with others, that there would be no trouble when idling, but the engine equipped with a fuelizer will idle as well, if not better, than one not so equipped. The burned gas is practically inert; the condition is like admitting free air to the mixture.

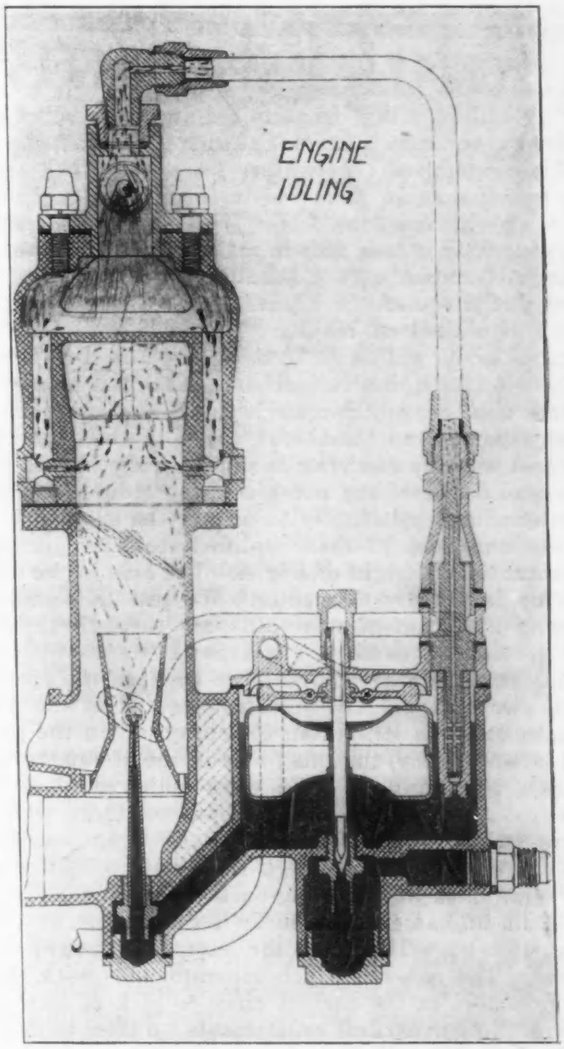

FIG. 5—CROSS-SECTION OF THE FUELIZER AS USED ON A TWIN-SIX PASSENGER CAR

K. B. BRITTON:—Is there complete combustion?

MR. WOOLSON:—That depends largely upon the quality of the mixture. We have made no exhaust-gas analysis. We can tell by the color of the flame in the burner body what kind of a mixture there is. We know that combustion is aided by having high compression but in the case of the fuelizer we are carrying on combustion in a partial vacuum. As soon as the tricks of burner-body design are known, it is easy to insure combustion under all conditions. In a wide-open throttle condition, the volume of mixture drawn through the burner body is very slight. No appreciable heat is given off under wide-

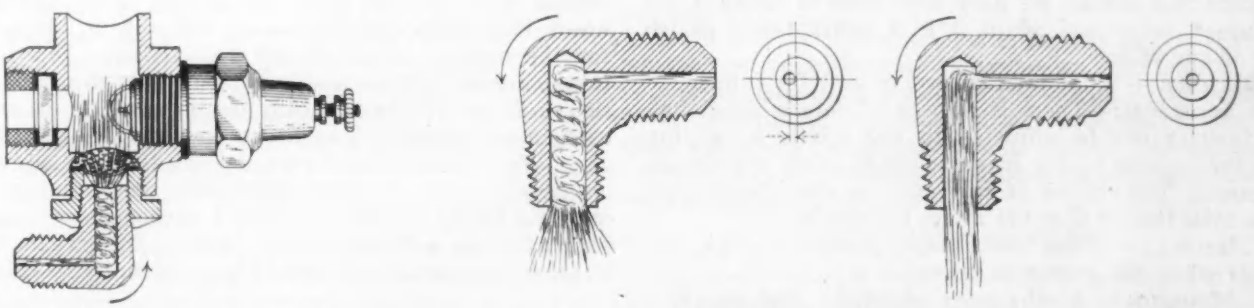

FIG. 6—SKELETON VIEW OF THE BURNER BODY AT THE LEFT. THE CORRECT FORM OF ATOMIZING ELBOW IN THE CENTER AND THE INCORRECT FORM OF ATOMIZING ELBOW AT THE RIGHT

open throttle, because the amount of gas in the burner is limited.

The drawing at the left of Fig. 6 shows what conditions must be obtained to get combustion. It is important that the mixture be atomized and distributed evenly in the burner body; it is not effective to distribute it unless it is atomized. Atomizers for oil for fuel purposes are complicated in form; so we began designing atomizers. We hit upon the design shown rather accidentally, and we have not been able to make an atomizer work any better. A screen with a peculiarly shaped orifice is located at the top of the burner body. Certain shapes of orifice give the best results. The spark-plug has a loop terminal and a gap of 1/8 to 3/16 in. The theory is that any time an inquisitive mechanic takes out a plug with a wide gap, he will narrow it down and cause trouble. It is important to locate the spark in the right place. The best working condition is shown in Fig. 6. The glass inspection window has not given any trouble and offers an interesting opportunity to inspect the operation.

Two conditions of the simplified atomizer are shown at the center and right of Fig. 6. The hole in the central drawing is slightly off center. We test these holes by allowing a stream of water to pass through them. If they are not off center we get the effect shown at the right. There is a great difference between the operation of the two sprays. The screen is located at the proper distance below to straighten the spray out in the burner body. Incidentally, the small hole in the atomizing elbow prevents popping-back. We were bothered at first by popping-back; when combustion started, there would be a flare-back that made the pipe hot. That was solved simply. The velocity through the elbow was increased. That eliminates any popping-back tendencies. The hole is 3/32 in. in diameter on the Twin-Six engine.

Fig. 4 on page 245 shows the later development of the fuelizer. The passage which communicates with the elbow is located in the correct place to pick off the right mixture. In our earliest experiments we tried to do that, but it is surprisingly difficult to pick off a uniform mixture from a carbureter of this type; a spotty mixture is obtained. But by experimenting we determined the design shown in Fig. 4, which gives uniform results. This design enables us to set a carbureter by the color of the flame in the fuelizer. The fuelizer will burn all kinds of mixture except the very richest. At the lean end, the fuelizer will burn a leaner mixture than the engine will run on. Through the glass shown over the burner body we are able to see the color of the flame. It is surprising how the color changes with the mixture. A perfect mixture is represented by a sky-blue flame; the electrode gets bright red. A rich mixture will give an emerald green color. In a very rich mixture, the liquid gas can be seen. This carbureter is somewhat unconventional in design in that the throttle is distant from the jet. Since we made this design we have been able to simplify the picking-off point and adapt it to a conventional carbureter of any make.

A MEMBER:—What mixture works best for idling?

MR. WOOLSON:—There is no way of determining that. The fuelizer can be adjusted to use mixtures varying from the richest to the leanest; there is no perceptible difference. The volume of gas is such a small percentage of the total that it does not affect the whole.

A MEMBER: — What percentage passes through the fuelizer when the engine is idling?

MR. WOOLSON:—At the most about 0.4 pint per hr.; about 5 per cent.

A MEMBER:—Is that for wide-open or closed throttle?

MR. WOOLSON:—At wide-open throttle very little mixture goes through the fuelizer.

A MEMBER:—What is the pressure drop at wide-open throttle?

MR. WOOLSON:—It may be from 1½ to 2 in. of mercury. I am not prepared to state accurately. On the other hand, there are many constrictions between the vaporizer and the burner body. There is no perceptible amount of flame with less than 6 in. of mercury depression in the burner body.

H. B. MASSEY:—What experience have you had at 10 deg. below zero fahr.? Will the fuelizer heat before the engine starts firing? Can its heating be depended upon?

MR. WOOLSON:—If the choke is pulled out it will invariably light. We paid particular attention to that.

MR. MASSEY:—At 10 deg. below zero, about how long does it take to crank the engine?

MR. WOOLSON:—About 3 sec.

A MEMBER:—How long will it burn with one spark?

MR. WOOLSON:—It can run without any spark. No spark is needed after starting, but a spark is necessary after sudden acceleration. In cold weather it is desirable to get all the heat obtainable.

A MEMBER:—What is the difference in mileage with and without the fuelizer, under the same conditions?

MR. WOOLSON:—I have made tests under flat running conditions. I obtained 15.5 miles per gal. without and 15.2 miles per gal. with the fuelizer; the difference is very slight. Under severe conditions, such as a series of accelerations, the improvement in acceleration due to the fuelizer will give better mileage with it than without.

A MEMBER:—If the acceleration were the same, would better mileage be obtained with the fuelizer than without it?

MR. WOOLSON:—Yes, acceleration is improved about 20 per cent by using the fuelizer and the pedal can be held down for a shorter length of time.

A MEMBER:—What percentage of the fuel entering the manifold is vaporized before reaching the cylinder?

MR. WOOLSON:—All I can say is that a sufficient portion is vaporized to give us what we need; it is of no advantage to go further, but we could increase the amount of heat.

A MEMBER:—What is the difference in carbonizing, with and without the fuelizer?

MR. WOOLSON:—Our claim for the results regarding carbonizing is based on the knowledge that we experience no spark-plug trouble. If the spark-plugs do not foul, it is reasonable to suppose that the carbon deposit is not formed. Detonation has more to do with the causing of carbon deposits than any other factor. Mr. Kettering, Mr. Horning and others are working on this problem. When we eliminate detonation, we will get rid of a main cause of carbon deposit. A deposit of the same depth of carbon with present-day fuels causes twice the spark knock that high-test fuels cause and this is responsible for the general complaint of carbonizing. This device takes care of carbon resulting from the burning of kerosene. There will be naturally more carbon in an engine using a wet mixture than in one in which the mixture is dry. We found we could run at least 1000 hr. and show no carbon on the fuelizer screen when the mixture was correct. If the mixture is rich, a carbon deposit occurs within 500 hr. and necessitates cleaning the screen. With a correct mixture it will burn clean indefinitely. That is

(Concluded on page 254)

Addresses at the Annual Dinner

THE Annual Meeting terminated on the evening of Jan. 13 with the highly successful Society dinner at the Hotel Astor, over 1100 members and guests being present. After appropriate remarks, President J. G. Vincent introduced Past-President C. F. Kettering as toastmaster for the evening. The other speakers were David Beecroft, then president-elect of the Society; R. E. M. Cowie, vice-president of the American Railway Express Co., whose subject was the Coordination of Transportation Media; and George E. Roberts, vice-president of the National City Bank, New York City, who spoke on the Crux of the Present Economic Situation.

ADDRESS OF PRESIDENT-ELECT BEECROFT

I WISH to thank the fellow membership for the honor conferred upon me. It is a great privilege to have the opportunity of heading an organization of over 5000 men and to be president of an engineering society that is unique in that it represents a circle of industries. This circle is composed of eight distinct but closely related industries, all centered about the use of the internal-combustion engine. The automotive engineer probably requires the services of the editor more than other engineers because the piece of apparatus in which the internal-combustion engine is installed has gone into the hands of the average citizen of all the countries in the world and it is necessary, if we can get the information from the engineer, to carry the message to the users of this apparatus rationally as to how it should be used.

Editors think that this apparatus is yet far from being in a perfected state. We are glad to have the laymen agree with us in that. The motor car, which is not the oldest of this circle but is the largest, still has many problems ahead. We give all credit to those engineers of Europe who, in 1885, began bringing together the fundamentals, and we have wisely builded upon their early work. There is one great credit that goes to the Society of Automotive Engineers; namely, that it had the good judgment to take and translate into the requirements of this country those fundamentals that were so well worked out in Europe. It was very fortunate that our manufacturing centers were located in the region of the Great Lakes, bordering on one of the greatest agricultural areas in the world, an area that has already given evidence of being one of the great consuming areas of automotive apparatus. What is happening in this agricultural area is happening in all similar areas in the world. We could scarcely do anything else but develop automotive apparatus and translate it into what we now have. It was the voice of those thousands of square miles of country calling for apparatus, the voices of those 7,000,000 farmers demanding improved transportation and the voice of great areas with sparse population, requiring some speeded-up method of transportation in order that the homogeneous character of this country should be maintained and that the urban population should not lead the rural too far, that induced automotive development. What has been a greater factor in bringing the rural population up to the level of the urban population than the internal-combustion engine in its various forms?

We developed this apparatus and the great production plans that have carried internal-combustion-engined apparatus to the four quarters of this country. In the earlier years of the war we found the nations of the world knocking at our doors for this apparatus and we immediately gave heed. Soon, this apparatus, so well fitted for our areas of poor roads, great distances and sparse population, found itself excellently fitted for use by the nations of the world. We unconsciously came by a great heritage in that we builded in the zone of requirements where conditions were crude, whereas Europe had been building under conditions that called for a different type of vehicle. We have this great field ahead. We have found our factory capacity greatly expanded because of the war. We must give attention to the remainder of the world. The motor vehicle is an international piece of mechanism in all its forms and our engineers must look beyond the confines of their own country. I can think of nothing that would be more useful today than that these engineers go into other countries and see the conditions under which their apparatus must operate, see face to face the peoples who are destined to handle it, and then have due regard for those conditions in the improvement of the apparatus.

What must be the ultimate object of the engineer in all this apparatus? In its design he must recognize the work, the people and the environment, always keeping in mind that he is best serving this country and all the countries of the world to which our apparatus must go, when he designs and makes the apparatus so that it is easiest to purchase, easiest to apply to the job, easiest to operate and easiest to maintain.

ADDRESS OF R. E. M. COWIE

IT was aptly said by the toastmaster, in speaking of the different means of express transportation, that everything from a wheelbarrow to an airplane is included in our service. The express business began some 75 years ago. It was not dignified at the start even by a wheelbarrow, because the single individual who originated the industry relied upon a gripsack. Within a very short time his business increased enormously and he had to invest in this wheelbarrow, but even that proved too small for his needs and led him to obtain certain space in a stagecoach. From that the business turned to other modes of transportation, the boat on the inland waterway, the steam railroad and steamboats, and has developed now to include every known means of conveyance. Until a few years ago, the express traffic in the cities was carried almost entirely by horses and wagons, in these days regarded as a slow and tedious means of transport. The American Railway Express Co. employs today upon the Island of Manhattan 650 motor and 550 horse-drawn vehicles.

There is a very distinct place for the motor vehicle, whether propelled by electricity or by gasoline. There is just as distinct a place for the horse-drawn vehicle. It is unfortunate that horse-drawn and motor vehicles must operate in the same string of traffic. I do not know how that can be remedied in the densely populated cities, but the problem must be solved.

SIMPLIFICATION OF PRODUCT

The motor vehicle is a wonderful machine, but it is too complicated. It takes a high degree of intelligence and engineering skill to design a vehicle of so many different parts, coordinate those parts into one apparatus

and make it function successfully. Still greater ability is requisite to eliminate a number of those parts. The cost of upkeep of the ordinary motor vehicle makes the average man stagger. This is due in part to the present high cost of labor and material, but if there is any way to simplify the internal-combustion-engined vehicle, I advise that this be done. Forget about what competitors do. It seems to me sometimes that the sales department of the average automobile manufacturing company merely wants the engineering department to put on fancy appurtenances so that it can have some little points to talk about that competitors do not possess. Wipe all these off; eliminate from the chassis everything but the absolutely essential parts. The efficiency of the vehicle will thereby be increased, its cost of operation reduced, and a greater field for its sale opened. The motor vehicle may appear to a scientific man to be a very much simplified machine, but we cannot get scientific men to operate our motor vehicles. The simpler the machines are, the more efficient they are, the less liable to trouble and the more economical in operation and upkeep. I cannot imagine any line of study that can be more profitably followed by automotive engineers than the simplification of the product in which they are interested.

The value of the motor vehicle as a means of transportation cannot be overestimated. The things that it has accomplished are marvelous. When the United States decided to enter the recent war, money and motor vehicles were preeminently needed and these two things were immediately found and furnished in this country. The engine that automotive engineers designed and the motor vehicle that they constructed won the battle of the Marne, prevented the fall of Paris and changed the whole complexion of the war. It was possible for the United States Government to furnish, for itself and for the Allies, vehicles to motorize the artillery, the ambulance service, the food service, supply and ammunition trains and everything that must follow up or precede an army, because the automobile industry was upon a sound, going basis and foundation.

Fostering of Commercial Aviation

The United States Government should adopt a far-sighted, consistent and constructive policy with respect to commercial aviation. It is true that the Government has, through meager appropriations by Congress, been able to conduct certain mail routes which, considering all the circumstances, must be admitted to be signally successful. I can conceive of no good reason why the Government should not encourage and support commercial aviation in the same manner that it has encouraged and supported navigation on the seas. In the one instance the Government furnishes maps, charts, lighthouses, whistling buoys, life-saving apparatus and the like. Why should it not furnish landing fields, illuminated airdromes, wireless directional apparatus, licenses, proper legislation and all the things calculated to make commercial aviation successful? From an experience of many years in the transportation business, I believe that the people of this country would avail themselves very quickly of service by air, just as they availed themselves quickly of service by parcel post. The parcel post attracted and built up a business peculiar to itself. I predict that the airplane service, where it covers a sufficient distance to eliminate a certain amount of time, will be taken advantage of immediately by the commercial interests of this country. Commerce presistently demands the most approved and expeditious means of transportation. I hope that soon the United States Government, through its mail department, and the American Railway Express Co. will join traffic and use the same machines to encourage commercial aviation. These must be specially built machines for carrying the Government mails and the extra emergency shipments offered by the public for express transportation.

In my judgment, the possibilities of commercial aviation offer the members of the Society of Automotive Engineers as great a field of endeavor as any field they have entered.

REMARKS OF C. F. KETTERING

We have not really awakened yet to a realization of what aviation is. If we talked about everything the way we do about aviation, we would still be riding around in ox-carts. I have said time and time again that we have a lot of people riding in automobiles who have ox-cart minds. The great trouble with aviation is that we do not appreciate what a tremendous thing it is. We do not appreciate the meaning of an increase in the speed of transportation of from three to five times what we have ever had before. The idea is too great for people to grasp. We certainly wish to thank Mr. Cowie for his stimulating message to this audience in favor of aviation. When an unbiased, unprejudiced individual talks that way, those are wise who pay some attention to what he says.

There are two kinds of aviation, military and civil. We have had two aviation clubs in this country, the American Flying Club and the Aero Club of America; but they have come together and made a good landing in that the two have now become the Aero Club of America. The club has a membership now of 2000, of whom 850 are pilots. We want to increase that membership so that members of the Aero Club of America will reside in every town, village and hamlet in this country. We want members to have a feeling that belonging to the Aero Club of America means something. It is a pioneering of the most wonderful thing that mankind has ever created for his own use. The automobile is wonderful and has fulfilled in a wonderful way the requirements of utility, but it must run on the ground. When flying in the air we can go straight and do not need any right-of-way. So let us support this Aero Club of America. Let us help to obtain these airports, lighthouses and other necessary equipment. We have airplanes and engines, but what would a great, massive railroad engine and its wonderful train be worth if we had no railroads to run them on? Today we have none of the essentials of aerial navigation; only by getting popular support will we ever obtain those essentials.

Most people when they go up in an airplane for the first time and the pilot gives them a "stunt" flight, come down and say that they would not accept $1,000,000 to do it again; on the other hand, if the pilot gives them the right sort of a flight, they come down and say that it was the most wonderful experience they ever had. Everyone ought to take a ride in an airplane. If an airplane passenger has any personal conceit, such an experience will remove it before he again reaches the ground. If one is general manager of some great factory, reaches an altitude of 5000 ft., looks back and sees a little bit of a factory about the size of a postage stamp, one is bound to realize that he is not so much, after all. Nothing else in the world will give one such a perspective of the relationship of individual activities to world activities as a flight in an airplane. I said, the first time I went up, that it looked to me very foolish to quarrel about

A PORTION OF THE GRAND BALLROOM

HE GRAND BALLROOM OF THE HOTEL ASTOR, NEW YORK CITY, WHERE THE ANNUAL DIN

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2 ft. on a line fence, one side or the other, and I still think that. So, we want the backing of everybody in the Aero Club of America. The aerial mail service is the great commercial laboratory for the flying machine, and yet I understand that Congress is in doubt about appropriating any money for it.

We have had two men speak about the necessity of studying automotive apparatus from the user's standpoint, and I think we all realize that this is a fundamental problem. Of course they are blaming all the faults on the engineers. No class of people realizes the faults of automotive apparatus any more than the engineers do, because engineers look over the trouble reports and others do not. Our whole economic situation has changed. We must build an entirely different type of apparatus in the future than we have in the past. We must recognize that the customer who pays for these automobiles has a right to ask for something, and that unless we design from the standpoint of the customer, we will get into trouble. If President-Elect Beecroft will focus his attention on that particular idea and print it and talk about it to the commercial side of the industry so that it will not overrule the engineers, that will help very much.

ADDRESS OF GEORGE E. ROBERTS

WE bankers have a consciousness that the automobile business has never felt under any particular obligations to the banking business for helping it to get started, and we are content to have it understood that a new business, as well as an individual prospective client, must make good before accommodations can be obtained from the banking business. The automobile business has made good. It has demonstrated that it is a utility, which is one of the things that was required of it. It is not always remembered that a banker is lending the funds that belong to others. He is a trustee for the funds in his possession, and he has no business to take any chances with them. It is not his business to promote new enterprises. He asked of the automobile business that the machine should demonstrate its durability; that it should demonstrate itself as a practical machine in the hands of the average man. It has demonstrated that. It has demonstrated that nobody who has ever owned an automobile will get along without one again, if he can avoid it, and that is good proof of success.

If anyone should know what is the matter with this world and the remedy for its troubles, it ought to be the engineer. He is not only the man to obviate its troubles but, in some degree, he is responsible for them. I mean by this that the primitive man did everything for himself and was independent, but gradually it was discovered that if a man devoted himself to one thing he acquired skill, and that if everybody devoted himself to one thing and all exchanged products with each other, there would be more of everything for everybody. So began the division of labor. Along with the division of labor came the engineer, who set about devising means to increase the productive power of the individual and to increase production, and along with the engineer came the development of capital. Capital, after all, is nothing but the machinery, tools and equipment that the engineer works with in production. The engineer, ever since, has been improving and developing the means of production, and always calling for more money. Thus it is that we have gotten this highly developed, intricate, highly organized state of industry that we have today.

One of our troubles is that the engineer has developed this industrial organization beyond the comprehension of the average man. So long as a man did everything for himself, he knew that the harder he worked, the more he would have. When he exchanged work with his neighbor, he had the whole transaction before his view; but when he works with thousands of other men for a great company, doing perhaps but one slight operation in the course of the production of an article, and the product is sold on the market, he has only a very small part of the process under his view. He loses his relationship to his fellow workers and to the consumers. He does not understand the process. He does not know very much about political economy. He does not know whether he is getting all he is entitled to or not, and he suspects that he is not. Moreover, this highly developed system of industry is wonderfully effective so long as it is working smoothly in perfect balance, with all its parts adjusted to each other, every branch of industry running to capacity and all branches exchanging products with each other; but it approaches the character of a great machine which, if any part is thrown out of order, is all brought to a standstill. That is the situation in which, to a very great degree, this country is at present and in which the world is at this time.

Industrial Depression

We are experiencing a period of industrial depression, and it is a world situation. We will not have any proper appreciation of the situation, its causes or the possible remedies, unless we understand from the beginning that it is a world situation. Wool has fallen, not only in the United States, but in Australia, Africa and South America. It affects coffee in Brazil, sugar in Cuba and Java, rice in India and silk in Japan. The people of all these countries are eager to sell their products, and to buy, and are unable to do either. Millions of people are out of employment and unable to buy the products of others because they cannot sell their own. This is not a general state of over-production. There never is a state of general over-production, but there often is, and there is now, a state of unbalanced production. The equilibrium throughout industry is the first requisite of a general state of prosperity.

We all understand that the unsound core of this whole situation is Europe. Europe was a great industrial community, gradually developed, accustomed to receive raw materials and food-stuffs from all over the world and to pay for them with its manufactured products. The war broke down this highly organized, slowly-developed, intricate, complicated system of industry and exchange, and it has not been reestablished since. This loss of the equilibrium in world trade has cost us our equilibrium in this country. It has reacted upon this country in the great fall in the prices of food-stuffs and raw materials. We have been accustomed to boast that our resources are so varied and so great that we can be practically self-contained and independent of the rest of the world. We could come nearer to being so that any other country. If we had organized and developed our industries with that purpose, we could be self-contained and independent to a very great extent; but our industries have not been developed with that thing in view. They have been developed as a part of the world industrial organization. Because of our marvelous natural resources we have found it to our advantage to develop those resources not only to supply our own wants, but with a view to supplying the needs of other peoples whose natural resources

are not so great as our own. We can work up into cotton cloth only about one-half of the cotton that is produced in this country; the same thing is true as to the consumption of food products and of raw materials of many kinds. Our people are and have been dependent for a part of their market upon foreign peoples. The inability of our foreign customers to buy the usual amounts and the falling off of that foreign market has disarranged our industry and thrown our industrial system out of balance. A state of general prosperity, either in international trade or in our domestic affairs, is impossible without an equilibrium in industry. There cannot be a free, full circulation of goods, a full employment of the people or the desired consumption of goods, unless the industries are in balance. All business, in the last analysis, is simply an exchange of products.

In the natural order of things, the population distributes itself in the various industries automatically in such a way as to keep them in balance, so that the products of each industry are absorbed by the other industries. Anything which suddenly disturbs that balance upsets the entire industrial system and prostrates industry throughout the country. That is exactly what has happened. Approximately one-half of the people of this country live either upon farms or in towns of less than 2500 people which are closely dependent upon farms. That end of our industrial system has been let down. Europe has let down the farmer and the farmer has let down our own industrial system. I need not tell you that a farmer whose income last year was $2,500, or $3,000, for example, and whose income from his present crop will not be over $1,200, or $1,500, cannot buy the same amount of factory products that he did last year. That is not a matter of opinon; it is a matter of arithmetic. That situation has to be understood and met. I do not wish to talk as a pessimist or as an optimist; I simply want to present the facts so that we can consider them as we talk about a speedy revival of industry. We may have our spurts of revival, but I believe there cannot be a general state of prosperity again unless the town industries and the great farming industry, with the people immediately dependent upon it, are brought back into a comparative state of balance.

Industrial Rehabilitation

I wish to present this thought, which is pertinent to the engineer. There cannot be a state of efficient production in a factory unless all departments are in balance with each other. I want to drive that point home. This situation may regain its balance through a rise of farm products, which has already taken place to some degree, but we must recognize that the price of farm products will continue to be dependent very largely upon conditions abroad and that it is beyond our control. The situation may improve through a general reduction of costs in the industries, so that the goods which the farmer and the general public buy come down to something like a normal relation with the other products which have already fallen in price. Either the one class of production must rise or the other classes must come down. We all know that it is comparatively easy to bring wages and prices up together, because everybody cooperates in the effort to raise prices, but when it comes to reducing prices many obstacles are in the way. The length of time required to regain prosperity depends upon the length of time it takes the business community to grasp the truth that industry and business must be brought back into balance.

No one likes to say much about reducing wages. I do not blame the wage earner for not wanting to accept lower wages but, in considering wages, we must consider all the rising wages and rising prices of the last 5 years. Then we must realize that all those things that went up together must come down together; at any rate, they must be brought together in some way before we shall have again a general balanced state of prosperity. The wage earner naturally says that he does not want to lose the gains which he made during the war. I do not want to see him lose them but, if the cost of living comes down, if flour and meats cost only one-half as much as they did before and if the farmer is feeding the city population at one-half the cost of a year ago, it is no sacrifice on the part of the town populations to take a reduction in their wages. It is not only no sacrifice; it is right. It is no more than what is just in bringing the situation back into balance. It is not a sacrifice because there is nothing else that can be done. It is a mere fiction to say that wages are maintained because wage rates are maintained. If one-half the wage earners are walking the street or working only three days in a week, their wages are reduced. Under such circumstances as exist now, they will be reduced, no matter what the agreement may be between employers and employes. All the employers of an industry and all the wage earners in that industry, together, do not have it in their power to fix the amount of wages that will be paid in that industry. The amount of wages that will be paid in any industry depends upon the amount of goods that can be sold, and the amount of goods that can be sold depends upon the ability of the public to buy.

One other way in which the situation can be met, that will appeal to the engineer, is by improvements in the methods of industry. Automotive engineers have led the world in that respect in recent years. They have shown the whole world how industry can be revolutionized by highly organized production. They have been teaching lessons to all the industries. They have done more than any other set of men to teach the lesson that the essential thing about wages is not the wage rate per week or per day, but the cost of labor per unit of product. That is the golden key to the solution of this entire industrial problem. The interests of wage earners, employers and consumers, can be reconciled by increasing production. We have the task of convincing the great body of people of this country that they are interested in large-scale economical production, and of convincing the wage earners of this country that they are interested not in restricting but in increasing production. In reducing the cost of all the necessities and the comforts of life, we must appeal to them. They must have a vision of the part they can play in the development of society. There is no limit to the improvements of that kind that can be made.

Money and Credit

There are those who think that the bankers are to blame for this reaction in industry, because they have been restricting credit or, as some have said, contracting credit. The best answer to the charge that they have been contracting credit is the record of bank loans in this country. The report of the Comptroller of the Currency shows that between June 30, 1919, and June 30, 1920, the bank loans of the United States increased approximately from $24,000,000,000 to $30,000,000,000, about 25 per cent. The bank loans of this country have increased twice as much since the armistice as they did during the war. There has been no increase in the physical production of the country in that time and no increase in the

amount of goods exchanged in the country. Therefore, why should there be such an increase in the amount of money or credit required to carry on the business of the country? Someone will say that wages and prices increased and that more credit was required to carry on business. Wages and prices did increase, but what made them increase? That raises a controversy as old among economists as the one in natural history as to which came first, the egg or the hen. Did the rise of prices cause the inflation of credit, or did the inflation of credit cause the rise in prices?

If there is anything that economists agree upon, it is that if the amount of the circulating medium, the supply of money in circulation or of credit which is in circulation as purchasing power, increases faster than the amount of goods to be exchanged, the value of the circulating medium will depreciate, and this means a rise of prices. The first impulse to the rise of prices came, no doubt, from the war. The war created an enormous demand for labor and for materials. The Government let contracts by the wholesale and the contractors bid against each other for labor and supplies. The ordinary demands of business in trade did not fall off because, with full employment for everybody, rising wages and the enormous disbursements of the Government, trade was better than ever. The banks were called upon, as a matter of patriotic duty, to lend money freely to support business and to people who would buy bonds. They did so on the theory that it had to be done to increase production. So long as there was any slack in the industries, these loans did increase production, but after every man is at work and every machine is running, that is about all that can be done. The point is reached where the most obvious way in which one employer can increase his output is by stealing labor from another employer. This is what was done. A procession of wage earners moved from one plant to another and had their wages raised at every move. When an organization is running to its capacity, if an attempt is made to drive it harder, all that is accomplished is to drive wages and prices up. That is what occurred and that is what brought out of the war this high level of wages and prices.

After the armistice there was a pause. Business men hesitated for a time to ascertain the trend of affairs. It developed that the private demands in industry would take the place of the war business. The soldiers were absorbed into the industries. In a short time the demand for goods, labor and materials was as great as it had been during the war. The war situation was repeated. Everybody had more business than he knew how to take care of, and there was the same pressure upon the banker for credit. In such a situation there is grave danger that the free granting of credit will simply finance a competitive struggle for labor and materials and drive the rising price movement still higher. Every merchant naturally wants to buy all the goods that he thinks he can sell. Every manufacturer wants to make all the goods that he thinks he can sell. But if the sum of all they think they can make and sell is greater than the capacity of the industries and in excess of the labor capacity of the country, and if every bank grants loans freely to its customers so that they can bid, nothing is done except to drive wages and prices still higher.

The fact is that people think credit can take the place of capital to a greater extent than is possible. Credit is purchasing power. Things can be bought with credit, but they cannot be made with credit. Labor and materials and machinery are needed to produce things. Credit is an intangible thing; it is faith and confidence. Capital is always something tangible; it is real estate or machinery or materials. I repeat that if credit is granted so freely that the supply in circulation increases faster than the capital actually in use, nothing is accomplished except to drive wages and prices upward. This is the reason that the banks of the country, alarmed by the enormous and rapid inflation of credits and under the advice and counsel of the Federal Reserve authorities at Washington, decided about a year ago to make an effort to hold this inflation in check.

The Dangers of Prosperity

Some people think, apparently, that a bank can grant any amount of credit, but it cannot do so. A bank is not a creator of wealth in the sense that a factory or a farm is; it is a reservoir of the liquid wealth of the community. It receives what is put into it and, under a sound banking policy, somebody must put into a bank every dollar that is paid out. Beyond that, all landmarks and guideposts are lost; there is no guide except the demand for money. The great trouble with our people is that they do not realize the danger of a great body of indebtedness on a high level of prices. They do not stop to think that, while their assets may shrink rapidly, their debts will not shrink at all. In Iowa, where the people have been exceedingly prosperous in recent years, if anybody had been able to predict the amount of money that they would receive for their products in the next 5 years, and if that prophet had never read history and did not know anything about human nature, he probably would have said that at the end of 5 years they would all be out of debt. The Department of Agriculture at Washington made an inquiry into the value of farm lands in Iowa last spring. It was found that the average value of all the lands in the State had increased $63 an acre from March 1919 to March 1920. The people of Iowa felt that they were prosperous and that they were entitled to credit. They proceeded to use it. The Federal Reserve Bank at Chicago recently made the statement that its loans within the State of Iowa were at that time 247 per cent of the normal quota which the State was entitled to.

In Cuba, there never had been such a state of prosperity as there was in the last 5 years. One might think that Cuba would get entirely out of debt and be rich ever after. Today, the people of Cuba are living under a moratarium established to relieve them of the necessity of paying their debts, this having been done to save the credit situation from a complete collapse. The fact is that people never use the earnings of good times to pay their debts. They use their earnings as the basis for further borrowing. They make their debts in good times and pay them under pressure in hard times.

Present Situation and Outlook

Although there is a period of quiet business while an adjustment is being made, the situation of this country is remarkably good considering the experience through which it has passed and the readjustments which were absolutely necessary. It has developed that the general condition of the business community is good, under all the circumstances, and in some respects very favorable to early recovery. In the past, in every similar situation, the reaction in business has come after a period of expansion under which a great amount of development and construction work had been done in the country, after a period of railroad building, of general city building and of over-expansion in that direction. That is not the situation at this time. We have had this period of expan-

sion, not because of construction work of that kind, but because of our expenditures upon the war. It was stimulated largely by the war business, and the fact is that this country is under-built today. There is a great backed-up demand for development and for construction work, which will speedily be done if the general conditions in industry are made favorable to do it. The railroads of this country need to spend literally billions of dollars to bring their capacity up to the needs of the country. A great house-building campaign should be carried on. The automobile business is behind the development it would have had except for curtailment during the war.

I reiterate that the industries of the country must be brought back into balance. Industrial costs must be lowered; construction costs must be lowered before we can hope for a general and complete revival of business. There is an obligation upon every class interested in prosperity to look the situation squarely in the face and see what part each individual ought to perform in bringing about this necessary readjustment.

THE PACKARD FUELIZER

(*Concluded from page* 248)

the reason it is important to insure a correct mixture. The later forms of fuelizer show an improvement in that respect. It is reasonable to suppose that the driver will adjust his mixture control to obtain the best mixture.

A MEMBER:—If carbon is deposited on the screen, can it be burned off with a different mixture?

MR. WOOLSON:—No, but it can be scraped off. The screen may require cleaning every six or seven months, but with the correct mixture it will run indefinitely.

A MEMBER:—Does the heat transmitted through the fuelizer walls or that contained in the burnt gases do the most good?

MR. WOOLSON:—Both sources are used about equally.

A MEMBER:—Is there no volumetric sacrifice?

MR. WOOLSON:—Not with a wide-open throttle. As soon as the throttle is opened wide enough, the flame goes out.

A MEMBER:—Is there any difficulty due to oxidation of the screen?

MR. WOOLSON:—No, it is made of ordinary brass.

A. J. SCAIFE:—Is the screen used on the new design?

MR. WOOLSON:—Yes.

E. W. WEAVER:—I note the infinitesimally small hole for the passage of the gas. Does that hole become clogged?

MR. WOOLSON:—The only time it becomes clogged is during its manufacture. In the beginning we had to inspect it and supervise the washing process to get the chips out. It gives practically no trouble in the car. The bottom of the vaporizer is only ¾ in. below the level of the gasoline in the float-chamber; the remaining distance is 1½ in. The tendency is to keep particles away from that hole; furthermore, the gasoline is entering the float-chamber and 95 per cent is supplied to the main jet. There is every chance that the main jet will get the obstructions.

A MEMBER:—Is any trouble caused by dust?

MR. WOOLSON:—We have had no trouble from that source. We locate the air inlet where we think there is no dust. Many persons thought we would have trouble with dirt, but that has not been the case.

A MEMBER:—Can this fuelizer be applied when kerosene is used for fuel?

MR. WOOLSON:—I have run on kerosene repeatedly. It will run on kerosene, but I believe it cannot be made to start. It might be possible to start with kerosene by using electric heating methods, but the ordinary way is to start on gasoline and then turn on kerosene.

A MEMBER:—Can more heat be provided?

MR. WOOLSON:—Yes, but we are not doing that now.

A MEMBER:—If heat were supplied, would the fact that an inert gas is used cut down detonation?

MR. WOOLSON:—I think it would, but it is something that is associated with a wide-open throttle. That is the wrong way to kill detonation; it kills the engine power. It must be cured in a way that will increase the engine power.

A MEMBER:—What is the temperature of the gas in the manifold while idling?

MR. WOOLSON:—That depends upon how long the engine idles. It will get extremely hot in time. We have had so much heat on the manifold that the thermometer registered from 200 to 400 deg. fahr.

DILUTION OF CRANKCASE OIL

(*Concluded from page* 237)

was no further trouble. I hope that the automotive industry can face the difficulty in the same way. I have an example in a six-cylinder car that has been sold in very large quantities. One of these cars ran about 14 miles per gal. of gasoline, and used a large quantity of oil. The owner replaced the rings and saw that they were properly fitted on the pistons. He obtained a slight improvement in the gasoline consumption and a great improvement in that of oil. After running the car several months that way, he dismantled the engine, ground the cylinders to a true, round condition and replaced the piston-rings; the fuel consumption was reduced to 20 miles per gal. of gasoline and the oil consumption was reduced two-thirds.

I discussed this question of grinding cylinders with a maker of quantity-production cars. He said that it can be done for less than $1 per cylinder. Unfortunately, when the American owner begins to economize, he begins to economize on the first cost. Very few people in this country buy for quality and for the long pull; until they do, we will have the difficulty that what is right from an engineering and from the long-pull point of view costs somewhat more at first and makes a greater sales resistance. The same condition is met in the oil industry. I feel that the engineers of the automotive industry must design and build for the long haul and for economy so far as their commercial and sales departments will permit them to do so.

Need for Researches on Automobile Parts

By William T. Magruder[1]

Annual Meeting Paper

The work of automobile testing laboratories has largely followed the example set in the last 40 yr. by steam-power laboratories. Tests on engines and materials have become common, while high-grade tests of fuels have been made only in a very few research laboratories. Tests on some one appliance have been made and the results buried and forgotten in the archives of the manufacturer of the particular appliance without their being made known to the automobile world. The time has now come when greater attention must be given to the smaller parts and to the various appliances found on automotive machinery.

Previously investigations have been made by the research laboratories of a few companies manufacturing engines, carbureters and a few other parts, but chiefly of engines; of research corporations, including the Bureau of Standards and the Bureau of Mines of the Federal Government; and of the engineering laboratories of our colleges of engineering and technical schools. It is hardly to be expected that private research laboratories should give to the world, even through this Society, the results of experiments which have cost from one to several hundred thousand dollars per annum, although it must be admitted that they have erred on the side of generosity rather than of selfishness in this regard. The number and value of the researches which can be conducted and reported on from time to time by Federal and State-supported institutions and universities depends entirely upon the appropriations that they can obtain by act of legislation and upon the personnel of the men attracted by the opportunity to do this class of work. It would therefore seem to be to the interest of the members of this Society to advance the research work being done by Federal and State institutions, and to see to it that adequate appropriations are made by our Congress and the General Assemblies of our states, and that those problems which most greatly need solution should be attacked first and all according to a guided program.

Research work in the engineering laboratories of state universities is done either by the instructors for their own interest and pleasure, or for their clients, or by the students as thesis work under the direction of one of the instructors. For these purposes, manufacturers are usually very generous in supplying material, if the laboratory will supply the testing equipment, fuel and labor. The colleges are glad to get this assistance even if the agreement is not always 50-50, and more frequently is 20-80, as it keeps them in touch with the manufacturing world.

Engine Tests at Ohio State University

In the last 20 yr. a number of tests of automotive machinery and parts have been made in the Mechanical Engineering Laboratory of the Ohio State University. It is thought that an outline of some of these tests may be of interest to the members of the Society in connection with this discussion of the subject. The friction of the engine can be determined by running an engine under load, absorbing the power by an electric dynamometer, and, when it has become thoroughly heated up, closing the throttle and carbureter valves and driving the engine from the dynamometer as a motor, and measuring the power required to drive the engine at various speeds, with and without the magneto, fan, valve-gear, or pistons. For example, it is of interest to learn that it requires about 2.5 hp. to drive a Ford engine at 700 r.p.m.; 3.0 hp. at 900 r.p.m., or at 22 m.p.h.; 3.5 hp. at 1000 r.p.m.; and 4.2 hp. at 1100 r.p.m., without current being generated by the magneto. With current from the magneto, from 0.2 to 0.3 hp. additional is required. That these results are low, as should be expected, as compared with the frictional horsepower developed when the engine generates its own power, can be shown by the statement that the frictional horsepower of a Ford engine, as determined by a number of different operators, varies from 4.5 to 4.7 hp. at speeds of from 800 to 900 r.p.m. These results were obtained by equating the pounds of fuel per indicated horsepower per hour at a given speed and for different loads, where the indicated horsepower is the sum of the measured brake horsepower and the unknown frictional horsepower, and solving for the frictional horsepower. With this figure available, the mechanical efficiency of the engine can be obtained with an accuracy depending upon the accuracy of the work and the correctness of the assumption, and will vary with the newness and tightness of the parts and how well they have been run-in.

The temperature of the jacket water of a certain water-cooled, four-cylinder engine was found to have a very decided effect upon both the operation and the power of the engine. Due to the intake mixture being preheated by partial contact with the exhaust manifold, preignition began, with gasoline as the fuel, when the inlet jacket water reached a temperature of 175 deg. fahr., became excessive at 190 deg., and caused a great reduction in power when the inlet water was 210 deg. The radiator cooled the water only by virtue of the fan and not by the car passing through the air, as in practice. By passing cold water in at the top of the radiator and drawing some of the warm water off at the bottom, thereby keeping the temperature of the outlet cooling water at 150 deg. fahr., it was possible to increase the power of the engine from 17.26 hp. to 18.26 hp., while increasing the gasoline consumption from 0.669 to 0.685 lb. per hp-hr. With kerosene, preignition began at 135 deg. fahr. By excess cooling, the maximum horsepower of the engine with kerosene under normal conditions was increased from 16.67 hp., using 0.89 lb. per hp-hr. to 19.36 hp., using 0.91 lb. per hp-hr. Excessive use of fuel caused this engine to give 18.41 hp., using 1.520 lb. of gasoline per hp-hr.; while with kerosene the maximum power was increased to 19.40 hp. when using 1.436 lb. per hp-hr. This means that 61 per cent more kerosene used gave 16.1 per cent more power, and that 127 per cent more gasoline used gave 6.6 per cent more power.

The maximum horsepower of this engine was 22.64 at a speed of 1043 r.p.m., when using 1.110 lb. of kerosene per hp-hr., and 21.07 hp. at 1020 r.p.m., when using 0.725 lb. of gasoline. The use of an excessively hot

[1] Aff. Rep. S. A. E.—Professor of mechanical engineering, Ohio State University, Columbus, Ohio.

manifold on this engine caused the maximum horsepower to change from 21.6, when the manifold was cool, to 16.1 hp. when the manifold became heated. This is a change of 5.5 hp., or a drop in power of 25 per cent. These results may be due in part to the tests being made in an open laboratory rather than on the road, but they seem to point to the desirability of having larger radiating surface than was provided with this engine. Again, numerous tests go to show that the proper jacket-outlet temperature for maximum power and minimum fuel consumption is a function of the shape and fit of the pistons and rings and the thickness of the jacket-water space.

Power Tests

The power lost in the transmission has been determined in this laboratory in two ways. The first is by measuring the speed-drop for increased loads for fixed settings of the carbureter needle-valve, throttle-valve, timer, and other variables, and noting the decrease in speed when power was delivered through the transmission, rather than by the engine direct. By this method, the speed of the engine dropped from 900 to 869 r.p.m., corresponding to 1.35 hp., when the fan was used; and from 900 to 769 r.p.m., corresponding to 3.30 hp., when the transmission was used. Second, by comparing the horsepower delivered by the engine alone to the horsepower delivered through the transmission to the belt-pulley of the tractor, and measured by the brake pulley, the loss between the engine and the pulley was found to be 3.25 hp., or 16.75 per cent of the maximum normal power of the engine. This result checks quite closely with the former. A third method, not yet used, is to insert a torsion dynamometer between the transmission and the differential, or between the engine and the transmission, when this is possible.

The power delivered by the rear wheels is best measured by mounting the machine on calibrated dynamometer brake-drums. When the rear wheels are replaced by special brake pulleys, an unknown allowance should be made for the frictional load due to the weight of the car on the wheels. A third way that has been tried with fair satisfaction is to replace the rear wheels by sprocket wheels and drive the chain pinions on the ends of the electric dynamometer shaft by chains or link belts. In this case what is measured is not the power delivered by the wheels, but the power delivered by the chains, and this varies with different speeds and loads. When due allowance is made therefor, very satisfactory results can be obtained in measuring the power required to drive certain parts under a variety of conditions, including those with and without compression in the cylinders. A fourth method, usually used in tractor testing, is to absorb the power from the belt-pulley delivered by a belt to an absorption dynamometer. As in the previous cases, allowances must be made for the power required to drive the belt and the dynamometer at different speeds, at initial tensions and whether the belt is open or crossed. In tractor plowing under quantitative test conditions, it has been noticed that only a small decrease in speed will cause the sod to be turned over very differently and without being pulverized, so that a difference of 10 per cent in speed will turn good plowing into bad.

Springing of the Chassis

We have been prevented financially from testing a motor car under its own power when mounted on calibrated dynamometer brake-drums having very irregular surfaces, simulating the effects of cobble-stones on the springs, and measuring the power required to drive the car at different speeds on brake-drums of varying roughness. In the scheme proposed, rays of light were to be reflected from mirrors on the wheel hubcap and on some part of the car above the springs, and received on sensitized paper, to show the relative emotions of the two parts of the car.

The trustees of the Ohio State University are asking the State Legislature of Ohio for an appropriation of $80,000 for an addition to its present mechanical engineering laboratory building, so as to care for the instructional and research work in automotive engineering. It is requested that all members of this Society from Ohio, and those having Ohio interests and connections, use, if they feel so disposed, their influence as citizens and taxpayers in the next few months to secure an adequate appropriation for the benefit of those students who desire to get professional instruction and experience in automotive engineering, rather than in some one other branch of engineering.

ECONOMICAL SIZE OF FARM

THE small farmer, generally speaking, works under a great many handicaps as compared with the farmer having a larger acreage. Students of the farm management and economics have known for a long time that, other things being equal, the returns from a farm business are practically in direct proportion to the size of the farm; that is, the larger the farm, the greater the net income. Of course it is easy to go too far in trying to farm a large acreage and do such a poor quality of work that the crop suffers. It is not meant to recommend this sort of practice but merely to show that frequently time can be spent better on additional acres than on overpreparation of a smaller acreage. The best solution of the small farmer's problems is to increase his acreage to permit him to utilize his labor and that of his hired hands to the best advantage through the use of large and efficient machines and at the same time keep the overhead charge, due to investment, etc., at a minimum figure.
—A. P. Yerkes in *Power Farming.*

NUMBER OF FATAL AUTOMOBILE ACCIDENTS

THE National Safety Council has secured statistics from its 41 local branches and the 8000 industrial plants, trade organizations and Government agencies included in its membership. These indicate that the 80,000 deaths caused by accidents in 1919 should be divided as follows:

Home and Public Accidents, other than automobile	47,000
Industrial Accidents	22,000
Automobile Accidents	11,000

While a condition under which half as many persons are killed in automobile accidents as in all industrial accidents is a very serious matter and one deserving the earnest consideration of the entire country and more especially every branch of the automobile industry, the National Safety Council feels that a very great injustice is being done that industry through the circulation of exaggerated statements concerning the number of persons killed in the year 1919 by automobile accidents.

Need for Greater Service Accessibility in Car Design

By T. F. Cullen[1]

Chicago Truck and Tractor Meeting Paper *Illustrated with* Drawings

FOR years past we have been designing cars for production accessibility, in other words, so that the various parts could be made and assembled at the lowest cost. Complaints are frequently heard, however, to the effect that a great many cars are not as accessible as they might be for service work, notwithstanding they may be 100 per cent accessible for assembly at the factory. As a car is assembled only once at the factory, however, and is certain to be disassembled and put together again, in varying degree, a great many times in the service stations of the country, it is important that this subject of service accessibility receive greater attention.

Many of us are prone to overlock the fact that upon the car owner's satisfaction depends the success of both factory and dealer. The car owner is the man who pays all the factory salaries, other expenses and profits; he is the man we are all working for, though we may not all realize it. Everything that can be done to reduce upkeep and the maintenance cost of the car will tend to increase the owner's satisfaction. Of the various items of expense in connection with maintaining a car, depreciation is probably the largest single one, especially during the first year or two of the car's life. Insurance, garage expense, repairs and adjustments, tires, gasoline and oil follow in about the order given. Improved service accessibility would tend to reduce repair and adjustment costs by decreasing the amount of repair labor for any operations that are necessary from time to time, and would also tend to retard depreciation by enabling the owner to keep his car in good running order at a minimum expense. Moreover, the fact that a car is unusually accessible for all classes of repair work will enhance its resale value as a used car.

Every unnecessary complication in car design adds to the time required for necessary service work, and therefore robs the car owner of just that much money sooner or later. Greater accessibility for service work also tends to lengthen the life of the car, as it makes service work easier to perform, less costly and therefore more likely to be undertaken at the first indication of trouble. The supply of skilled mechanics is never large enough to fill the demand. Any improvement, such as better service accessibility, which cuts down the time per operation in service work without impairing the car's subsequent efficiency, has exactly the same effect as increasing the number of skilled mechanics. With more accessible cars, service stations could turn out more work with fewer mechanics and therefore make bigger profits, or show a profit where they now show a loss, as many of them do. The dealer's success, both in selling cars and in servicing them, is just as essential to the factory as the owner's satisfaction.

More and more cars are sold each succeeding year to replace worn-out vehicles. Service reputation, based on the cars now in use, is rapidly becoming the predominating factor in these resales. Therefore anything that can be done to improve service work will make resales easier in future. As an example of the results which could be secured by improving service accessibility, it is only necessary to recall that there are over 8,000,000 cars in use today, and improved design which would reduce the time necessary for service work to the extent of only 2 hr. per car per year, would save the owners over $15,-000,000 per year on upkeep.

Status of Car Design for Service Accessibility

Before attempting to point out how car design can be improved in the direction of greater service accessibility, it is necessary to know where we stand now. For this purpose I made a survey of 40 representative cars of all types and schools of design, including 4 and 6-cylinder and V-type 8 and 12-cylinder engines, and covering a wide price range. These cars were rated according to their comparative accessibility for 25 typical service operations, consisting principally of such operations as are likely to be required a number of times per year on the average car, together with a few operations which might be needed occasionally as the result of accident or worn or broken parts. No attempt was made to cover all operations or extensive overhauls. Each make of car was rated on the basis of 100 points for the most accessible design possible for all 25 of these typical operations or four points for the best design for each operation. A tabulated list of these 25 service operations, together with the ratings of the different cars, and the average rating of all cars and groups, is presented on pages 258 and 259.

Note that some of these service jobs required much less time than others but those taking the least time must be performed most frequently in the ordinary course of events, so that this method of rating gives very fair results for purposes of comparison. Where certain operations are not required on some makes of cars due to their design, the remaining operations were prorated. Accessibility of the car for these various operations was the only factor considered in rating the different cars. The ratings given were arbitrary, depending on the necessity, or otherwise, of removing other parts to get at those affected, the need of special tools, awkward position of the mechanic, etc. For obvious reasons, the names of the cars are omitted from this table, the different makes being referred to by number only.

It will be evident on studying this table that there is considerable room for improvement in service accessibility of the average car with respect to most of the operations covered in this survey, and the natural inference is that there is at least an equal opportunity for improvement with respect to other service operations. On a few operations the average ratings for all cars were

[1] A. S. A. E.—Managing editor, *Automobile Trade Journal*, Philadelphia.

COMPARATIVE SERVICE ACCESSIBILITY OF 40 REPRESENTATIVE

Operation Number	OPERATION / Car Reference Numbers	FOUR-CYLINDER CARS 1	2	3	4	5	6	7	8	9	10	11	12	13	SIX-CYLINDER CARS 14	15	16	17	18	19	20
1	Test battery or remove and replace	4	4	4	4	3	4	4	3	4	3	3	3	4	4	3	1	4	4	2	3
2	Tighten fan-belt	3	4	4	4	4	4	3	4	3	4	4	3	4	4	3	2	4	..	4	4
3	Paint springs with graphite and oil	4	4	3	4	4	4	3	3	4	4	4	4	4	2	3	3	3	4	4	4
4	Flush crankcase and refill	3	3	4	4	4	4	4	4	4	4	4	4	4	3	4	4	4	4	4	4
5	Tighten spring clips	3	4	3	4	3	4	4	4	3	4	4	3	3	3	4	4	4	4	4	4
6	Clean out gasoline line	3	4	3	3	3	4	4	4	4	4	2	2	4	3	2	2	3	4	3	3
7	Repack water-pump	2	4	..	..	..	1	..	..	2	..	4	4	4	4	..	4	4	..	4	3
8	Replace all hose connections	4	2	4	4	3	2	4	3	4	4	4	3	3	4	2	2	4	..	2	2
9	Adjust brake bands and pull-rods	4	3	3	3	3	4	3	3	3	3	3	3	4	4	2	3	3	3	3	3
10	Install and sand in new generator brushes	3	4	2	3	3	3	3	3	3	2	3	2	3	2	2	2	2	3	4	4
11	Replace and adjust breaker points	3	4	4	4	2	4	3	4	4	4	1	4	4	3	4	3	3	2	4	4
12	Clean oil-pump intake	4	4	4	4	1	4	3	2	1	4	4	4	4	2	4	3	4	4	4	4
13	Adjust clutch	1	3	4	3	3	3	3	3	4	2	4	3	4	3	2	4	4	3	4	3
14	Replace fan-belt	4	4	4	4	3	4	4	4	4	1	2	4	4	4	2	2	4	..	4	4
15	Grind valves and remove carbon	4	4	4	4	4	4	4	3	4	2	4	2	4	2	4	1	4	1	2	4
16	Removeand replace carburreter	4	3	4	4	3	4	4	4	4	3	4	3	4	2	3	3	3	3	3	4
17	Remove and replace geneator	2	4	4	3	3	3	3	4	4	1	4	3	4	3	3	4	3	3	2	3
18	Adjust steering gear (remove play in wheel)	1	4	3	4	1	4	4	4	4	2	3	4	4	4	2	4	4	3	4	4
19	Reline all brakes	4	3	4	3	1	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
20	Adjust engine front end drive	3	2	4	3	3	4	2	2	2	2	4	4	4	2	3	3	4	4	4	3
21	Remove and replace starting motor	3	..	2	2	1	2	4	4	2	1	4	1	4	..	1	2	4	..	2	..
22	Replace one piston	2	1	3	4	4	4	3	4	3	4	4	2	4	2	4	1	4	1	2	4
23	Tighten one connecting-rod bearing	2	1	3	4	4	4	3	4	2	4	4	4	4	4	4	4	4	2	4	4
24	Install new rear spring or lower half	4	4	4	4	4	4	3	4	2	4	4	4	3	2	3	3	2	3	4	4
25	Replace camshaft	3	2	2	3	4	4	1	2	2	1	4	3	4	3	3	3	4	3	4	3
	Average per Car All Operations	77.00	82.29	86.46	89.58	73.96	89.00	82.29	85.42	79.00	72.92	88.00	79.00	95.00	75.00	72.92	70.00	89.00	76.25	84.00	88.54
	Price Class	Under $1,000	$1,000 $1,500	$1,000 $1,500	$1,500 $2,000	Under $1,000	$2,500 $3,000	$1,500 $2,000	Under $1,000	$1,000 $1,500	Under $1,000	$1,500 $2,000	Above $2,000	Above $2,000	$1,500 $2,000	$1,500 $2,000	$1,500 $2,000	$1,000 $1,500	$2,500 $3,000	$2,500 $3,000	$2,000 $2,500

very high and the individual ratings practically uniform. On some other operations, however, such as cleaning out the gasoline line, replacing hose connections, removing and replacing the carbureter and the generator, adjusting engine front-end drive, etc., there was considerable variation. The lack of uniformity between different operations on the same car, showing that cars which are quite good in some respects are radically inaccessible in others, should also be noted.

As might be expected, the four and six-cylinder cars show very nearly the same average values throughout, while those with V-type engines are, on account of their design, less accessible for certain operations around the engine. This does not necessarily indicate any serious defect in the V-type engine, as other factors not directly related to service work must be taken into account in determining the all-around desirability of any type of car; it is only the accessibility for service work that is being considered in this paper.

The cars covered by this survey include practically all price classes, but they are not arranged according to their selling price. For further aid in making comparisons, the price range on each car is given in this table. It is noteworthy that some of the lower-priced cars show up better in this survey than some of their more costly brothers, indicating that accessibility as it affects service work is not connected in any way with price. A low-priced car is usually simple in design, containing the minimum of parts, and it can therefore be made very accessible for service work. On the other hand, it may be very inaccessible, not because of a multiplicity of parts, but because the parts are not placed to the best advantage. In the higher-priced cars even a large number of parts

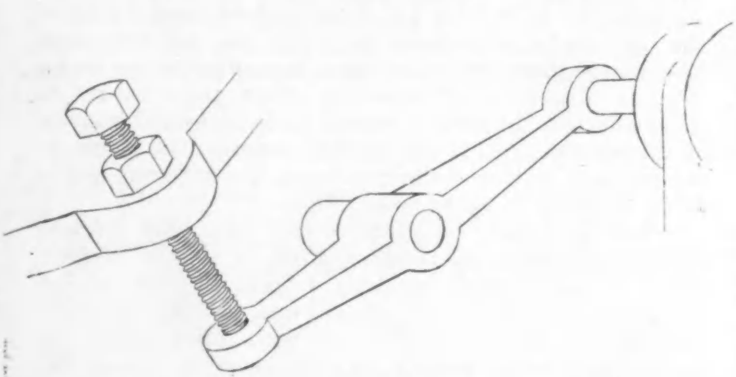


FIG. 1—A VERY SIMPLE TYPE OF FAN-BELT ADJUSTMENT

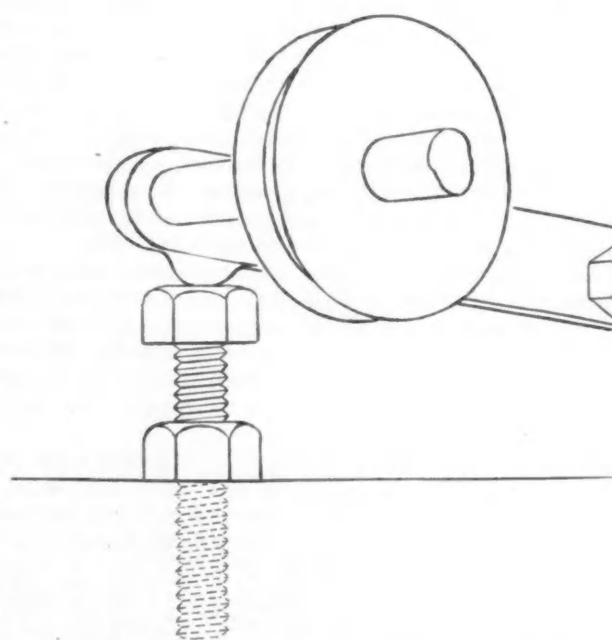


FIG. 2—ANOTHER TYPE OF FAN-BELT ADJUSTMENT WHICH IS CONSIDERED ALMOST AS GOOD AS THAT SHOWN IN FIG. 1 EXCEPT THAT THE ADJUSTING SCREW CANNOT BE TURNED WITH A SPEED WRENCH

CARS ON 25 TYPICAL SERVICE OPERATIONS

SIX-CYLINDER CARS														8 AND 12-CYLINDER CARS—V-TYPE						AVERAGES			
21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	All Cars	Four-Cylinder	Six-Cylinder	V-Types
4	3	3	3	4	4	4	3	4	3	4	4	4	3	3	4	4	4	3	3	86.90	90.40	84.50	87.50
4	3	4	4	4	3	3	3	3	4	3	4	3	4	..	4	4	1	..	..	88.20	92.30	87.50	75.00
4	4	4	3	4	3	4	4	4	4	4	4	3	4	4	4	4	4	2	4	91.90	94.20	90.50	91.70
4	4	4	4	3	4	4	4	3	4	4	4	3	4	3	3	4	4	4	4	95.00	96.10	95.20	91.70
4	4	4	3	3	4	4	4	4	4	4	4	4	4	4	4	3	4	3	4	93.10	88.50	86.40	91.70
2	2	4	4	4	4	4	1	4	2	4	2	4	4	3	1	3	4	2	4	78.75	84.60	77.40	70.80
4	4	..	4	1	1	2	2	3	3	4	..	3	2	1	2	2	4	2	3	72.50	75.00	76.50	58.30
4	4	3	3	3	4	3	4	4	1	4	4	4	3	1	4	4	4	2	2	80.10	84.60	80.00	70.80
3	4	4	4	3	3	3	3	3	2	3	3	3	3	3	3	3	3	3	3	78.10	80.80	77.40	75.00
3	3	3	3	3	3	3	3	3	2	3	3	3	3	3	3	3	3	3	3	71.90	71.20	71.40	75.00
4	4	4	3	4	4	4	4	4	4	3	3	4	1	3	4	4	4	2	2	85.60	86.50	86.90	79.20
3	4	4	4	2	3	4	4	4	4	4	4	4	4	2	2	4	4	4	4	87.50	82.70	91.70	83.30
4	3	4	3	3	3	4	3	4	4	3	3	4	3	3	2	3	3	3	3	80.00	76.90	84.50	70.80
4	3	2	2	2	4	4	4	3	4	3	3	2	4	..	4	4	2	..	..	83.30	88.50	80.00	83.30
4	4	4	3	4	4	4	4	4	4	4	4	4	2	2	2	2	1	1	1	79.40	90.40	84.50	37.50
3	4	3	3	4	4	3	4	4	4	2	4	4	4	2	3	2	2	2	2	82.50	92.30	84.50	54.20
3	3	2	3	4	4	4	4	3	2	3	4	4	4	1	4	4	2	3	2	78.75	80.80	81.00	66.70
4	3	4	4	2	4	4	4	4	4	3	4	4	4	2	4	3	3	3	2	85.00	80.80	91.70	70.80
3	3	4	3	3	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	76.25	75.00	77.40	75.00
2	2	2	4	3	1	2	2	2	2	4	3	2	4	4	1	2	3	2	1	68.75	75.00	69.00	54.20
3	2	3	2	4	4	4	3	4	4	3	4	2	4	..	2	2	3	3	3	70.00	62.50	76 40	54.20
4	3	4	2	4	3	4	4	4	3	4	4	4	4	3	2	3	3	1	1	77.50	80.80	82.10	54.20
4	3	4	4	4	2	4	4	4	3	4	4	4	4	3	2	3	3	2	3	85.60	82.70	92.90	66.70
4	4	4	2	4	4	4	3	4	4	4	4	4	4	3	4	1	4	2	4	87.50	92.30	88.10	75.00
2	3	2	4	3	2	3	3	3	2	4	3	3	2	1	1	1	1	1	1	64.40	67.30	73.80	25 00
87.00	83.00	86.46	81.00	82.00	83.00	89.00	84.00	89.00	80.00	88.00	89.58	86.00	85.00	64.77	72.00	75.00	76.00	60.87	67.39	81.30	83.10	83.30	69.60
$3,000 $3,500	$2,500 $3,000	$1,500 $2,000	Above $5,000	Above $5,000	$1,500 $2,000	$1,000 $1,500	$1,000 $1,500	$2,500 $3,000	$1,500 $2,000	Above $5,000	$2,000 $2,500	$1,000 $1,500	$4,500 $5,000										

need not seriously affect the service accessibility of the design.

POSSIBLE IMPROVEMENTS SUGGESTED BY SURVEY

During the course of this investigation many noteworthy designs were observed and in the accompanying sketches some attempt has been made to outline various designs which could be used without copying from any particular make of car. None of these sketches was made from any one make of car, but rather they are composites incorporating the best features as regards

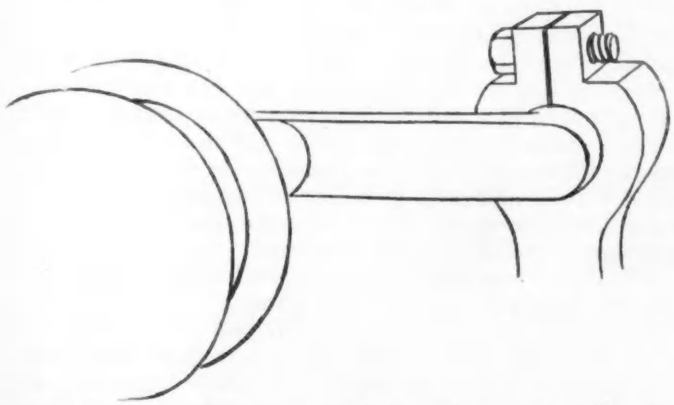


FIG. 3—IN THIS TYPE OF ADJUSTMENT THE FAN BRACKET MUST BE HELD IN POSITION BY A SPECIAL TOOL WHILE THE LOCKING SCREW IS BEING TIGHTENED

designing for service accessibility in the various cars examined. The illustrations cover only a few of the points taken up in the foregoing discussion that can be clearly illustrated. No attempt will be made to take up the location of parts of the car other than those connected with the survey already referred to. Even on these 25 operations, however, there are many little points in connection with designing for service accessibility that are worthy of mention.

In connection with operation No. 1, for instance, it developed that the most accessible location for the storage battery is under the right front floor-boards or under the right front seat. The battery is inspected very frequently and in many instances at a battery service station which has no garage facilities, so that the work must be done while the car is standing at the curb. Locating the battery on the right side of the car is therefore good practice from this standpoint. In a sedan with no front door on the right side, the best location for the battery seems to be under the rear floor, preferably near the right side of the car. It is hardly necessary to add that the terminal connections should be accessible, so that they can be broken with an ordinary open-end wrench, and the holding-down clips should be as simple as possible, preferably of the spring or wing-nut type.

In fan-belt adjustments there are several different designs which are giving good results in service. Fig. 1 shows a type of adjustment which has much to recommend it. The adjusting screw can be turned either with an open-end or a socket wrench, preferably the latter for

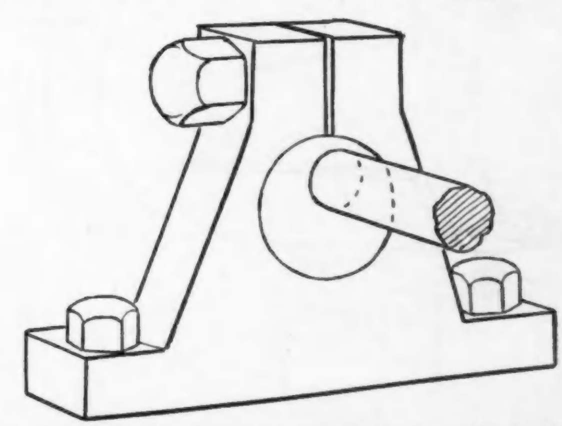


FIG. 4—AN ECCENTRIC TYPE OF FAN-BELT ADJUSTMENT USUALLY REQUIRING A LARGE WRENCH OR A SPECIAL SPANNER TO TURN IT

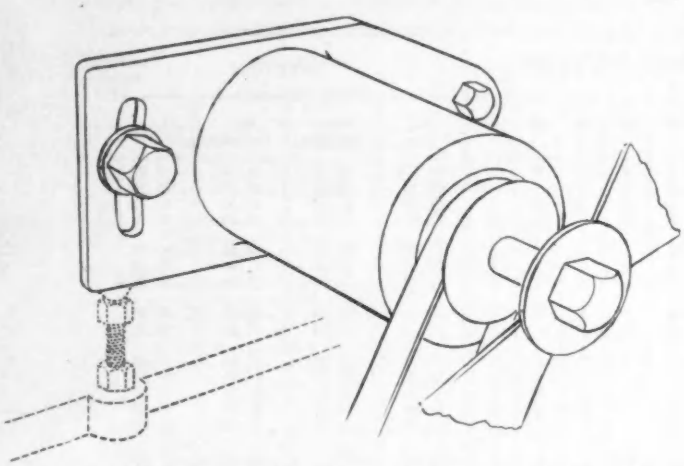


FIG. 5—MOUNTING FOR A BELT-DRIVEN GENERATOR IN WHICH EASE OF ADJUSTMENT IS SECURED BY PIVOTING THE BASE PLATE AT ONE END AND PROVIDING A SLOTTED ADJUSTMENT AT THE OTHER
An Adjusting Screw as Shown by the Dotted Lines Would Be an Improvement

speed. The adjusting screw should be easily accessible so that the lock-nut can be loosened readily. Probably it would be best to locate this adjustment so that the work can be done from the right side of the car, with the adjusting screw set at an angle as shown. Figs. 2, 3 and 4 on pages 258 and 259 show other types of fan-belt adjustment which also give good results, although I do not consider them quite the equal of that shown in Fig. 1 on page 258. With the adjustment shown in Fig. 2, for instance, it is necessary to turn the adjusting screw with an open-end wrench, and very often there is only a limited space in which to swing the wrench, owing to the proximity of the fan belt and blades. The principal objection to the adjustment shown in Fig. 3 is that the bracket or arm on which the fan shaft is mounted must be held in position either by hand or with a special tool, while the clamping screw is tightened. For this reason it is best not to use a nut on the clamping screw but rather a lock washer under its head. It seems preferable to make this adjustment also from the right side of the car. The eccentric adjustment illustrated in Fig. 4 gives good results, but the range of adjustment is usually more limited than with the types previously mentioned. With this device also it

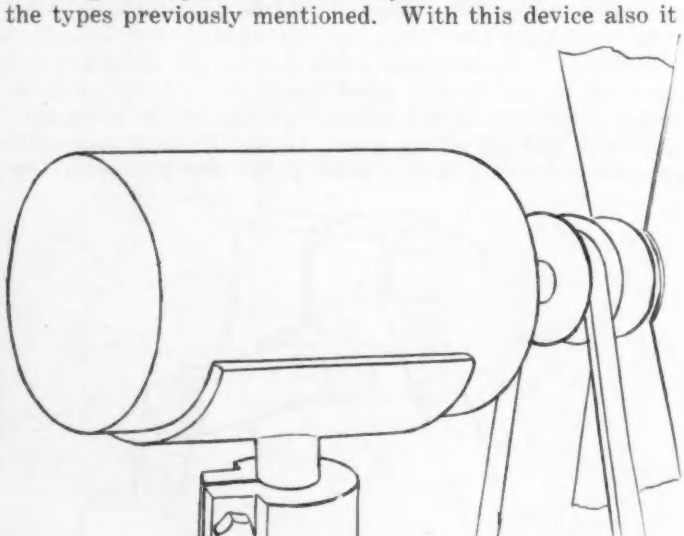


FIG. 6—ANOTHER TYPE OF MOUNTING WHICH IS OBJECTIONABLE BECAUSE THE GENERATOR MUST BE HELD IN POSITION EITHER BY HAND OR A SPECIAL TOOL WHILE THE CLAMPING SCREW IS TIGHTENED

is advisable to make the adjustment from the right side of the car, and to use a plain clamp screw with a lock washer under the head and no nut. Usually a large hexagon or castellated prongs are provided on the outer end of the eccentric to facilitate turning it. Perhaps a smaller hexagon, not more than ¾ in. across the flats, would be preferable, as a large wrench or special tool for turning the eccentric is not always available.

Figs. 5 and 6 illustrate two common methods of mounting a belt-driven generator with which the fan is incorporated. Fig. 5 shows the better method from the standpoint of service accessibility. Note that in this illustration the mounting plate of the generator is pivoted at one end, and a slot adjustment with clamping screw is used at the other end to hold the unit in place when the proper adjustment of the driving belt is obtained. An improvement might be made by locating an adjusting screw at some convenient point, as shown by dotted lines in this illustration. This would enable the mechanic to raise the generator easily to the proper point and hold it there while locking the adjustment. Without this added feature, it is necessary to loosen one or two clamping

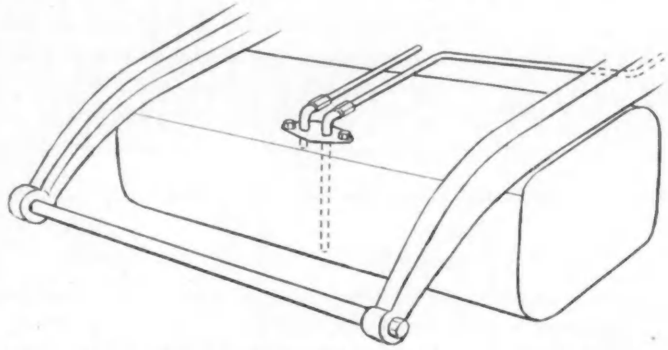


FIG. 7—THE GASOLINE TANK OUTLET CONNECTION SHOULD BE ACCESSIBLE FOR CLEANING THE FEED LINE
An Overhanging Body or Spare Wheels at the Rear Must Be Considered in Locating the Outlet

screws in the adjustment slots and raise the generator either by hand or with a special lifting bar, and hold it in place while tightening the clamping screws. This latter objection also applies to the type of adjustment illustrated in Fig. 6. The generator and fan assembly is a rather heavy unit to hold in place with one hand, or even with a special lifting bar, while tightening the adjustment. The position of the mechanic is sometimes awkward at best, and perhaps before he can get the clamping screws tightened enough to hold the unit in its proper position, it will slip down somewhat.

Front and rear spring clips can be located so that they can be tightened readily when necessary. The practice of placing the threaded ends of the rear spring clips upward with underslung rear springs is gradually being abandoned in favor of inverted U-shape clips passing over pads on the axle tube and projecting through cross plates under the spring. This puts the spring clip nuts below the spring where they are readily accessible, and is a step in the right direction.

Even such an operation as blowing out the gasoline line is difficult on some cars, due to the inaccessible location of the gasoline outlet connection from the rear tank, now used on the majority of models. Fig. 7 illustrates a type of connection which would appear to give the best results on the average car, except where the body overhangs the rear edge of the tank. In some designs no separate vent pipe is used, the vent hole being drilled in the filler cap. If spare wire wheels or disc wheels are

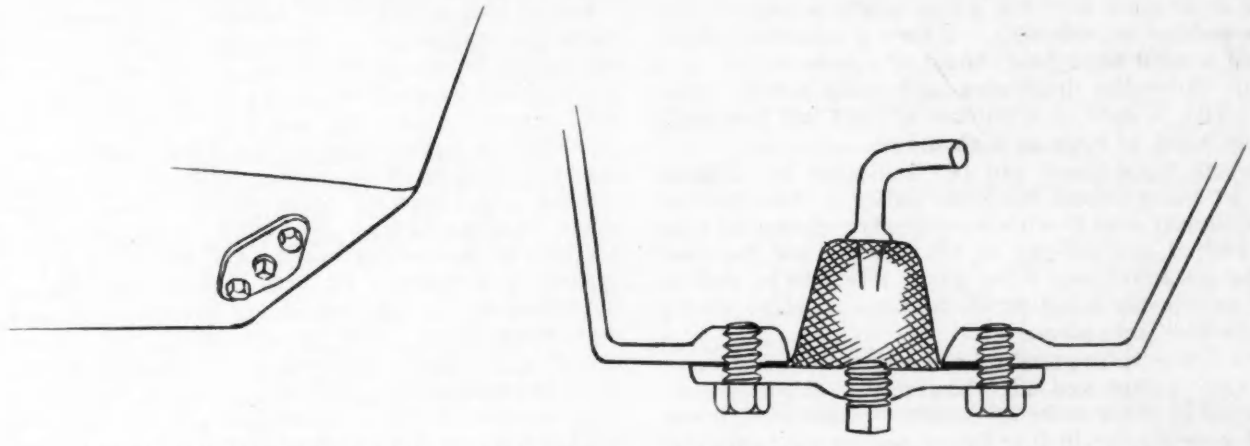


Fig. 8—Combining the Crankcase Drain-Plug with the Cover-Plate over the Pump Intake Screen Simplifies Construction

to be carried at the rear of the car, the gasoline outlet connection should be near one end of the tank and the filler-cap and gage near the other, so that it will not be necessary to disturb the spare wheel or wheels either in filling the tank or in cleaning out the gasoline line when clogged. The forward end of the feed line is usually accessible enough, as it is on top of the vacuum tank in a great many cases.

Water-pump packing-nuts are very inaccessible on many cars. They should be clear of the pump and not made inaccessible by being placed too close to other units, such as the generator and ignition unit, or between the back of the pump and the cylinder casting, or the front gear housing. Sufficient room should be allowed so that the packing-nuts can be backed off and repacked readily when necessary.

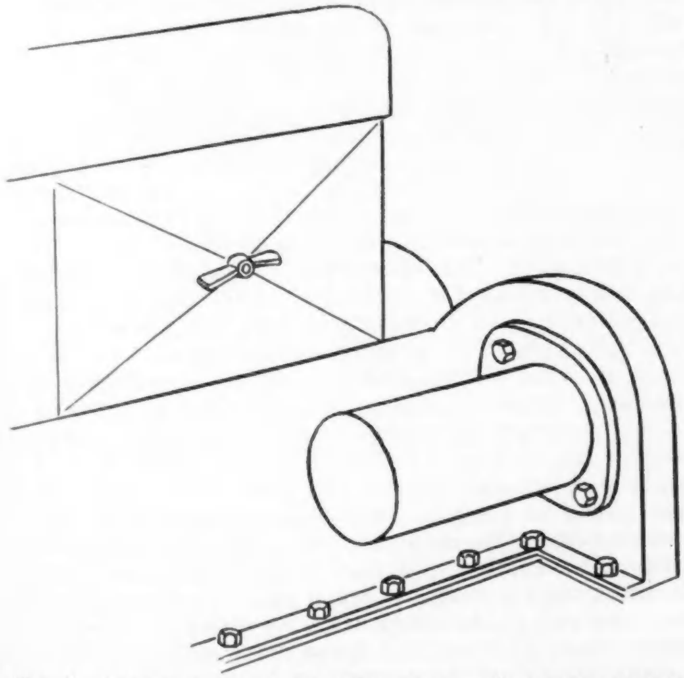


Fig. 9—An Accessible Attachment of the Generator to the Back of the Timing Gear Case where the Engine Uses a Gear Train in the Front End

Hose connections on different cars vary greatly as regards accessibility. Usually the upper hose is accessible enough, but the lower one may run under the forward crankcase arm or some of the other units around the front of the engine, making it very inaccessible for replacement. In some cars it is even necessary to remove the sod-pan to replace the lower hose. Where it is impossible to make this hose accessible in any other way, it would seem advisable to run it entirely under the sod-pan or provide a door in the latter.

Brake pull-rod adjustments could be made much simpler on a great many cars, first by placing the adjustments in the most accessible locations, second, by providing turnbuckles or other means of adjustment which could be altered without having to disconnect the pull-rod entirely. Where the rod must be disconnected to alter the adjustment, considerable time is consumed, as the alteration must be made, usually by the cut-and-try method, connecting up the pull-rod after each change and testing to see if it is correct.

The location of the oil-pump intake could be improved considerably from the standpoint of accessibility on a number of cars. Where the pump is located in the bottom of the crankcase, some such construction as that shown in Fig. 8 could be used. If the drain-plug is incorporated

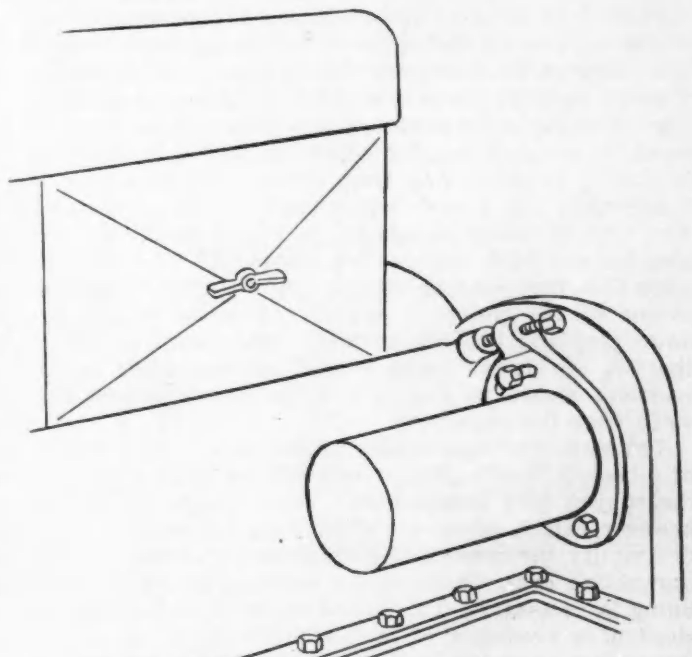


Fig. 10—Generator Mounting for Use with a Chain Drive in the Front End of the Engine and Which Is Employed as a Means for Taking Up Slack in the Chain

in the cover-plate over the pump intake screen, it simplifies matters considerably. Where a separate sod-pan is used, a good sized hole should of course be cut in it directly under the drain-plug and pump screen cover-plate. This is done in a number of cars but frequently the hole is not as large as it should be.

Fan-belt replacement can be facilitated by allowing plenty of space around the lower pulley, so that the belt can be slipped over it without difficulty. Sometimes the front end of the sod-pan or the ratchet for the hand starting-crank, or some other parts, interfere to such an extent as to make it a difficult and tedious job to work a heavy fan-belt into place.

To facilitate valve-grinding and adjustment, the valve-stems and springs and adjusting screws should be unobstructed by other units, if possible. Sometimes lowering the generator an inch or two or setting the carbureter a little farther out from the cylinder block would make a really remarkable improvement in the accessibility of the valve-stem adjustments.

Generators can be mounted in various ways, but the schemes illustrated in Figs. 9 and 10 on page 261, together with those in Figs. 5 and 6 on page 260, will serve to illustrate some of the possibilities for accessible mountings. Where a train of gears is used in the front end of the engine and the generator is driven by a gear meshing with the camshaft gear or another one in the train, the mounting shown in Fig. 9 can be used. An important detail is to locate the cap-screws holding the generator flange in position on the gearcase so that both are readily accessible. Many constructions use three cap-screws for this purpose, and it is inevitable with this construction that one of them will be very inaccessible. If it is possible to get along with two, locating them about at the angle shown in Fig. 9, accessibility would be much improved. The mounting illustrated in Fig. 10 is, of course, for use with a chain drive in the front end of the engine, in which the generator mounting is used as a means of taking up the slack in the chain. The usual practice with this type of mounting is to pivot the generator flange on one cap-screw and provide one or two other cap-screws in slots in the flange, so that the generator can be moved slightly to take up slack in the chain, and then locked in position. The adjusting screw shown in Fig. 10 is a slight improvement, as it makes possible adjusting the chain while the engine is running, and then locking the generator in place when the proper adjustment has been obtained. The type of mounting shown in Fig. 9 might be used also for attaching the starting motor. If it is felt that more than two points of support are required, to take the torque of the motor, it might be possible to use two dowel-pins and two cap-screws on the mounting flange, the two cap-screws being located approximately in the positions shown in Fig. 9, and the dowel-pins 90 deg. away from the cap-screws.

The matter of accessibility of brakes is almost worthy of a book in itself. No attempt will be made to go into the subject very deeply here. There is one little kink, however, which might be adopted on a number of cars to simplify the removal and replacement of the external contracting brake-bands on the rear-hub drums when relining is necessary. This is the use of a special bolt instead of a riveted stud in the outer end of the brake torque-arm, as shown in Fig. 11. When a riveted stud or a projection integral with this brake arm is used, the only way to remove the brake-band is by pulling off the rear wheel and sliding the brake-band outward. By using a special bolt at this point, however, it is possible to remove the brake-band by springing it slightly, and without having to remove the wheel. Where one of the brakes is on the drive-shaft or back of the transmission, and only external brakes are used on the rear wheels, this construction might improve the service accessibility of the rear-wheel brake mounting. Even on cars using both internal and external rear-hub brakes, this construction might be advantageous. The outer or contracting brakes are usually the service brakes, and the inner expanding brakes the emergency set with this construction, and in the hands of the ordinary driver the service brakes are used much more than the emergency set and consequently may require relining about twice as often. On those occasions when only the outer or service brakes require relining, this construction would facilitate the work by making it unnecessary to remove the rear wheels to get at the brake-bands.

The remarks made previously with reference to generator mounting where the generator is used as a means of adjustment for a chain drive in the front end of the engine, cover one form of engine front-end adjustment which is generally used. If it is impractical to use the generator for adjusting a chain drive, however, some other means of adjustment, easily accessible from the outside of the gearcase, should be provided. Needless to say, it should not be necessary to remove any parts to get at this adjustment. Where gears are used for the engine front drive, no means of adjustment is required, but it will be necessary occasionally to replace worn gears or to install a new set to get quieter operation. Even though this work may be required only rarely, it is advisable to make the front-end drive of the engine as accessible as possible. Where a three-point support is used, with a single support in the front and the remaining two on the flywheel housing, it is usually necessary to block up the front end of the engine at the crankcase before removing the front gearcase cover, for the reason that the front support of the engine is very often integral with this cover. This difficulty is not encountered where the four-point support system is used. But even with the latter type of construction there are a number of cars on which it is necessary to remove various units such as water-pumps, and occasionally generators or magnetos, before the timing-gear cover can be taken off.

In tightening connecting-rods and replacing pistons most of the work must be done from underneath the car; therefore a separate sod-pan is a great inconvenience unless it can be removed very easily. The bolts or cap-screws holding the crankcase lower pan in place should all be as accessible as possible. Wherever it is necessary to locate these in narrow spaces, as, for instance, across the back end of the crankcase, just forward of the flywheel housing, where the space is so small that it is impossible to start these screws by hand, cap-screws with lock washers should be used; never round-head screws. A standard hexagon-head cap-screw can be inserted in place as well as tightened up with an ordinary brace socket-wrench, but it is extremely difficult to start a round-head screw in a narrow space.

Removable cylinder-heads, of course, facilitate piston removal and replacement, but even where the solid cylinder-heads are used it is seldom difficult to design the engine so that pistons can be removed and replaced from below in case of necessity. A slight bevel at the lower end of the cylinder bore will help matters considerably, as this will serve the purpose of compressing the piston-rings when placing the piston in the cylinder,

thus rendering a special piston-ring compressor or squeezer unnecessary.

The remarks made with reference to the engine front-end drive apply to camshaft removal and replacement. Accessibility for easy camshaft replacement requires that any auxiliary units, such as the igniter or the oil-pump, when driven off the camshaft, be connected in such a manner that they will not have to be dismounted before the camshaft can be pulled out through the front end. Also these auxiliary gears must mesh readily with their driving gears on the camshaft as the latter is replaced. They should mesh either 1/8 in. or so before the camshaft gear meshes with the crankshaft gear or 1/8 in. or more after the main timing-gears have been meshed. This is, of course, to avoid difficulty in meshing different sets of gears, which would be encountered if they all came into mesh about the same time. Of course, where the engine front drive is by chain, this difficulty is not encountered. Usually when gears are used it is feasible to mount the large timing-gear on the camshaft before replacing the latter in the engine, to insure that it will run true. That is why the meshing of the auxiliary-drive gears operated off the camshaft is brought up in this connection.

Spring breakages, especially of rear springs, are not as rare as we would like to see them. Therefore, the rear spring mounting particularly should be so designed that spring replacements can be made as easily as possible. With Hotchkiss drive the front end of the rear spring is

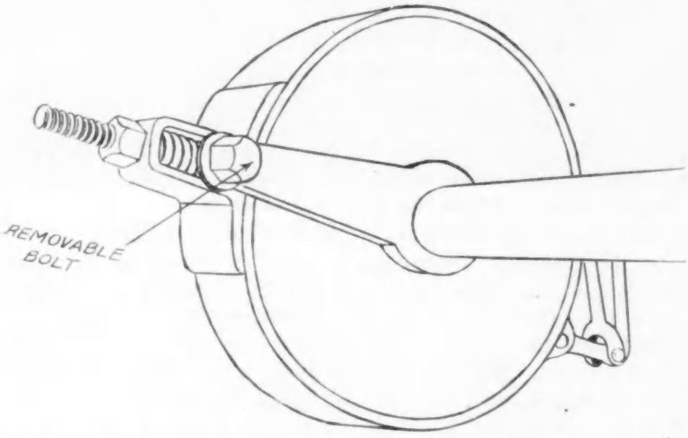


Fig. 11—Replacing the Stud on the Brake Mounting or Torque-Arm Would Make It Possible To Remove and Replace the External Brake Bands without Having To Remove the Rear Wheel

usually bracketed close to the under side of the frame channel. If the running-boards are dropped far enough below the lower edge of the frame, a hole can be provided in the running-board shield to make the forward eye-bolt of the rear spring accessible. Some cars were noted, however, in which this eye-bolt was almost if not quite in line with the running-board, making it difficult to get the eye-bolt out of the bracket. Of course the head of the bolt was toward the center of the car, but the nut on the outer end of the bolt was in a very confined space, and could be turned only with an open-end wrench.

In one or two cars the muffler location interfered with the removal of the forward rear-spring eye-bolt on one side. This could easily be avoided by moving the muffler forward a few inches.

In Figs. 12 and 13 an attempt has been made to illustrate how the various units can be disposed about the engine so as to make them all readily accessible, and in fact make the whole engine as accessible as possible for all service jobs likely to be required. Fig. 12 shows a

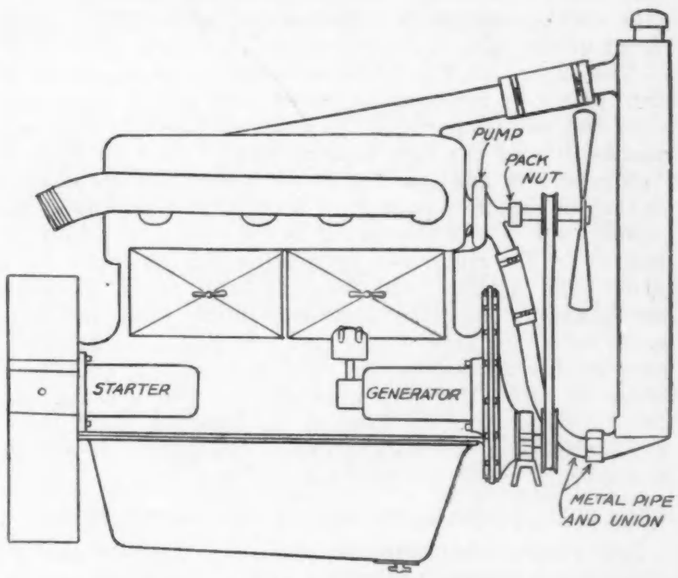


Fig. 12—An Example of How the Various Units Can Be Grouped about a Typical Three-Point Support Engine to Provide the Maximum Service Accessibility

vertical engine with three-point support, the single point being at the front end, with the pump mounted on the forward end of the cylinder casting and driven by the fan-belt with a single packing nut on the pump shaft where it is readily accessible. With this construction, the fan-belt adjustment must be made by bringing two halves of the upper V-pulley more closely together, or providing an idler pulley at some other point. Note that the lower hose connection is made accessible by locating it immediately under the pump and using only a comparatively short length of rubber hose and below that a metal tube connected to the radiator outlet by a union nut. The generator and starting motor are both located on the right side of the engine with mountings similar to that shown in Fig. 9 on page 5. The carbureter is assumed to be on the left side of the engine, but could be located on the right side if desired. By mounting it fairly high and setting it out from the cylinder block somewhat, it would not interfere with the accessibility of the valve-adjustment mechanism. The oil-pump strainer cover and

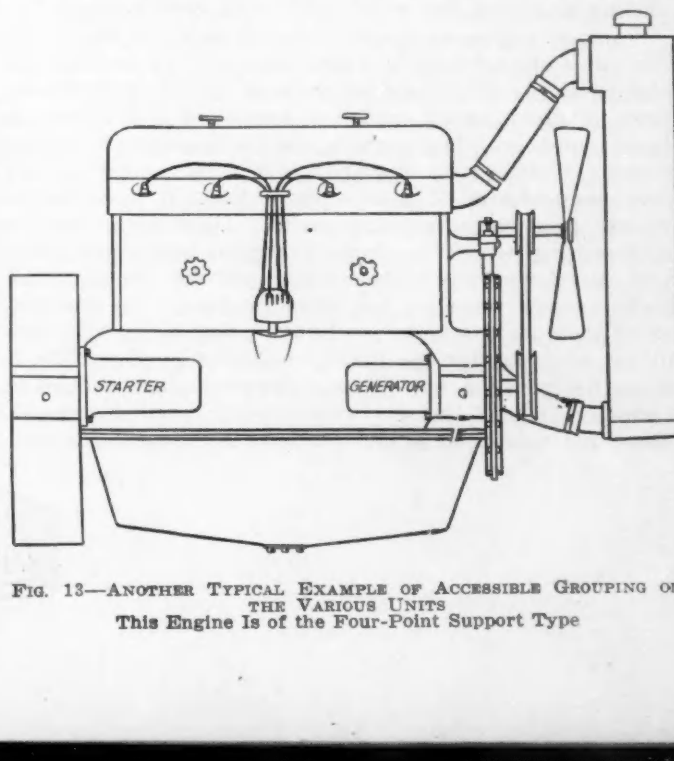


Fig. 13—Another Typical Example of Accessible Grouping of the Various Units
This Engine Is of the Four-Point Support Type

crankcase drain-plug are shown at the forward end of the crankcase sump where they can be reached from the front of the car.

The engine in Fig. 13 is assumed to be supported at four points by two arms at the forward end of the crankcase and two supports on the flywheel housing. Fan adjustment is of the type illustrated in Fig. 1 on page 2. The generator and starting motor mountings are similar to that in Fig. 9 on page 5. Thermosyphon cooling is assumed, but if a water-pump is necessary, it could be located on the right side by moving the generator back under the igniter and locating the pump between the generator and the front-end drive, with sufficient space on either side of the pump to make the packing-nuts readily accessible. In this connection it should be borne in mind that the generator on the average car will in all probability have to be removed much more frequently than the water-pump; consequently it should be the more easily removable of the two.

Possibilities for Improvement in Current Models

It is realized that extensive changes in current models which are in regular production and in which no changes have been contemplated, would be expensive; nevertheless there are many little ways in which the service accessibility of many of these models could be vastly improved without involving heavy outlay. By changing one thing at a time, as the factory stock of various units is gradually used up, it would be possible to work in a number of little improvements which in the aggregate would make the cars much more accessible and would cost the factories very little. On the other hand, it is safe to say that every such improvement would more than pay for itself in a short time.

Any designing engineer who is deeply enough interested in this subject could make up a chart or table somewhat along the lines of the one discussed earlier in this paper, picking out any typical service operations, and rate his own car in comparison with others of the same price class or type of design and also with some higher or lower-priced and of radically different design. It is safe to say that in making such a comparison he will run across many little features which could be incorporated in his own car in one form or another, or which would suggest improvements to him. If such a survey could be made by a good service man with technical training, or by a consulting engineer, the results might be even better.

Factory engineers should give more attention to the design of special tools and equipment for dealers' service stations to facilitate service work on current models, and even on discontinued models if these are still in use in large numbers. The dealer's service manager is seldom capable of designing special tools and equipment for his own use, and even if he can design them, it is expensive to get them made in single units. The time is rapidly approaching when the factory engineering department will consider service station equipment for the cars they build, just as necessary as assembly equipment and machine tools for the factory. In this respect the ideal condition would be for the factory engineering department, when designing a new car, to design it for production accessibility and service accessibility, and design all necessary special tools and machine equipment for producing the various parts, the factory assembly equipment and all the necessary dealer service station tools and equipment, all before the car is actually put into production.

It is suggested that when a new model is being designed, or at least some time before the car is put into production, the distributors and dealers' service managers be called into conference, if at all possible, or at least some of them who have both technical training and service experience, and that they be asked to go over the new car and suggest improvements which would make it more accessible for service work. Undoubtedly a great many suggestions will be obtained in this way, which can be incorporated in the car design without great expense, if acted upon before final provisions have been made for production. The service man meets the public or in other words the car owners, and knows their needs and wants better than the factory or designing engineer can possibly know them. If it is impossible or undesirable to get the service managers together, or to consult them individually, it is suggested that the factory engineer make up a list of all important service operations, rated according to frequency or importance, analyze the preliminary design of the new car in connection with these service operations and see what improvements can be made to render the car as accessible as possible for all service jobs or at least the most important ones or those most frequently required.

Some factories have taken a step in the right direction by establishing a rule that the engineers responsible for the design of a new car shall drive the car for a considerable period during its development and do all work on it themselves. Undoubtedly much can be learned regarding service accessibility in this manner, but the important thing is that the lessons learned in this way shall be used in improving the design of the car and not forgotten or neglected as soon as the test trip is ended.

In designing new cars or models it is important that special attention be given to all the necessary service operations on closed cars and special body types. Closed cars are becoming more and more popular and must be made just as accessible for all service operations as the open models. All the standard body types, both open and closed, which are used on any chassis, should be taken into consideration so that the car will be 100 per cent accessible for service work, regardless of the type of body preferred by the purchaser.

Another minor point worth mentioning is consideration of the possibility of damage to various parts of the car in case of accidents or minor collisions which will sometimes occur, and to design the car so that the damage resulting therefrom shall be minimized as much as possible.

In conclusion, I desire to point out again that this paper is intended only as an opening wedge and to call attention to a few of the many ways in which improvements in service accessibility are possible. The subject is a vast one, and it is impossible to go into it very deeply in a short discussion, but it is hoped that this paper and the discussion to follow will open up some possibilities for further improvement in car design from the standpoint of service accessibility.

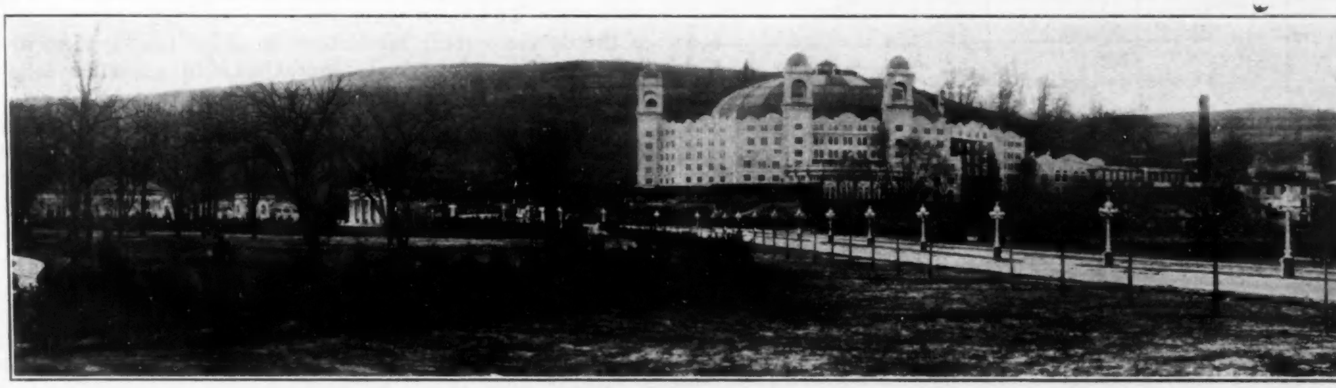
S. A. E. Summer Meeting

ARRANGEMENTS for the 1921 Semi-Annual Meeting of the Society have recently been completed and the Meetings Committee announces the selection of the West Baden Springs Hotel at West Baden, Ind., as the location for this year. May 24 to 28, inclusive, have been chosen as the meeting days, this period being about a month earlier than last year. West Baden was selected after a careful canvass of all of the places suited to the peculiar demands of a meeting of the size and character of that held by the Society. Since the Annual Meeting is always held in New York City, it is logical that a mid-western center should be chosen for the summer activities as in the past and it is desirable that the hotel appointments and grounds be of the best.

The beauty and unique character of the West Baden Springs Hotel cannot be exaggerated. The 520 rooms are arranged in a circle and the court in the center is covered, forming an immense room 200 ft. in diameter and 100 ft. in height, believed to be the largest room of this character in America, if not in the world. The hotel furnishings and equipment are in keeping with its unique architecture and equal to any found in our large city hotels. All of the rooms are large and comfortable and the majority have private baths connecting.

The facilities for recreation and the usual sports events could not be bettered. The golf course is situated on a large elevated plateau commanding a view of the entire surrounding country. The presence of numerous natural hazards results in a very sporty course and, in combination with carefully maintained greens, has made the course a favorite throughout the Middle West. There are tennis courts, a baseball diamond, swimming pool, and beautiful lawns where the customary sports program can be staged. Motion picture shows are given nightly in a special theatre; there are card and billiard rooms, bowling alleys and a swimming pool for indoor recreation; a stable of splendid horses is maintained for folks who ride. The surrounding country is exceptionally attractive and the general atmosphere of the spot is one of restfulness and health. The mineral waters at West Baden are well known for their medicinal value and every type of bath and treatment is provided. It is anticipated that very many of the members of the Society will prolong their stay at West Baden once they become acquainted with its charm.

The technical meetings can be conducted at West Baden under ideal conditions since there is a convention hall in the hotel which will be used as the principal meeting room. It is detached from the main lobby of the hotel and away from the noise and confusion which have been an annoyance at previous meetings. This room has a seating capacity of 750, has a high ceiling, and is constructed so that the view is nowhere obstructed by pillars. There are other excellent rooms available for meetings, and the plan of holding sessions simultaneously, which proved successful at the Annual Meeting in January, will be repeated. The program for the technical meetings has been outlined and indications point toward the presentation of papers that will be classed among the most noteworthy presented at Society meetings in the past. There will be sessions devoted to fuel, research, aeronautics, farm power, highways and transport and engineering relation to sales. The last subject is particularly pertinent at this time and should arouse unusual interest.



THE WEST BADEN SPRINGS HOTEL AT WEST BADEN, IND., WHERE THE 1921 SUMMER MEETING WILL BE HELD FROM MAY 24 TO 28

West Baden is 120 miles south of Indianapolis and it will be noted that the S. A. E. meeting closes on Saturday and Decoration Day falls on the Monday following. The members and their guests can arrange to attend the annual 500-Mile Race at Indianapolis on Decoration Day as part of their vacation because of this arrangement.

Negotiations are now being carried on with the railroads to secure the same reduced return-fare arrangement which undoubtedly influenced many members to attend the Annual Meeting in January. Special trains will be arranged from the principal automotive centers enabling the members to leave Monday evening, May 21, arriving in West Baden not later than the following noon. It is anticipated that many of the members and their guests will drive to West Baden and assurance is given them that proper garage facilities are provided at the hotel.

Compression Ratio and Thermal Efficiency of Airplane Engines

By Stanwood W. Sparrow[1]

Annual Meeting Paper *Illustrated with* Charts

It is only recently that the old definition of an engineer as "one who can do with one dollar what any fool can do with two" could be applied appropriately to the aviation engineer. His task has been rather to do, at any cost, what "any fool" could not do at all and to

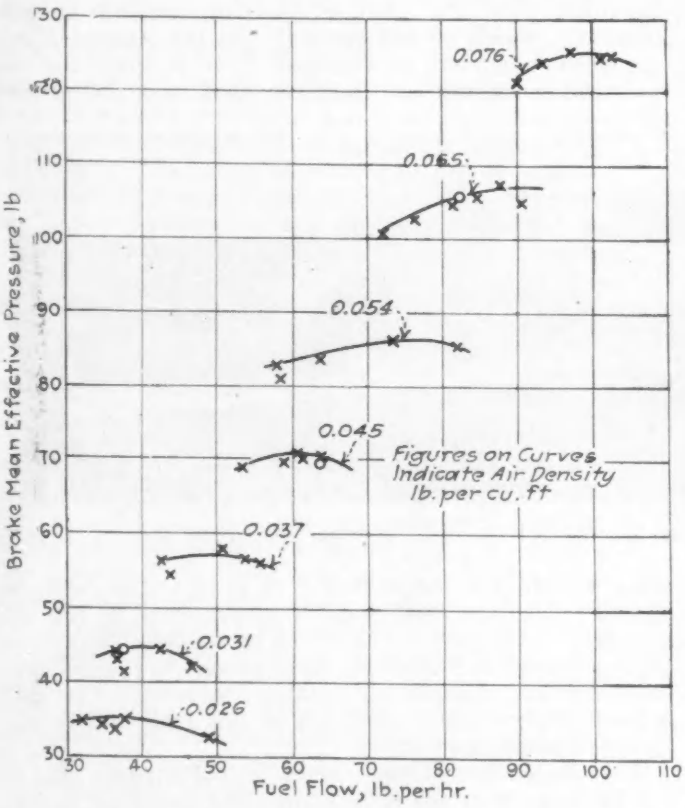


Fig. 1—Comparison of Brake Mean Effective Pressures Developed with Various Compression Ratios from the Same Amount of Fuel

his success the aeronautic achievements of the past year bear testimony. Now, however, it is assumed that the aviation engine will be reliable and of not unreasonable weight per horsepower, and the demand becomes one for higher efficiency or more miles per dollar. Foreseeing this demand and appreciating the fundamental relation of the compression ratio to the thermal efficiency, the National Advisory Committee for Aeronautics has sponsored a comprehensive investigation of this subject at the Bureau of Standards. Every effort has been made to measure the engine performance so completely as to make possible an analysis which will not only explain the results of this particular series of tests, but will also form a sound basis for predicting the effect of changes in the compression ratio on the thermal efficiency of any engine. Although not even the experimental work is entirely finished, it seems wise to present some of the more salient results at this time rather than withhold them for the more complete analysis.

For these tests an eight-cylinder airplane engine having a bore of 120 mm. (4.72 in.) and a stroke of 130 mm. (5.12 in.) was secured. Pistons were provided giving compression ratios of 5.3, 6.3, 7.3, and 8.3. These had all been run in in their respective cylinder blocks to insure a proper fit. The differences in the compression ratio were effected by crowning the piston-heads different amounts. The tests were made in the altitude chamber of the dynamometer laboratory in order that typical altitude conditions of air temperature and pressure might be obtained.

The tests which have been selected for consideration in this paper were made at full load with an engine speed of 1600 r.p.m. The temperature of the air entering the carbureter was in one case + 10 deg. cent. (50 deg. fahr.) and in the other — 10 deg. cent. (14 deg. fahr.). For each compression ratio the results were plotted in the manner shown in Fig. 1. This shows the brake mean effective pressure developed with different rates of fuel flow at altitudes from the ground to 30,000 ft. Although these curves show the effect of the air-fuel ratio on power, their real purpose was to make possible a comparison of the brake mean effective pressures developed with the various compression ratios from the same amount of fuel.

The air measurements showed that practically the same mass of air was taken per stroke with each compression ratio. Hence, the two curves of Fig. 2 apply to all of

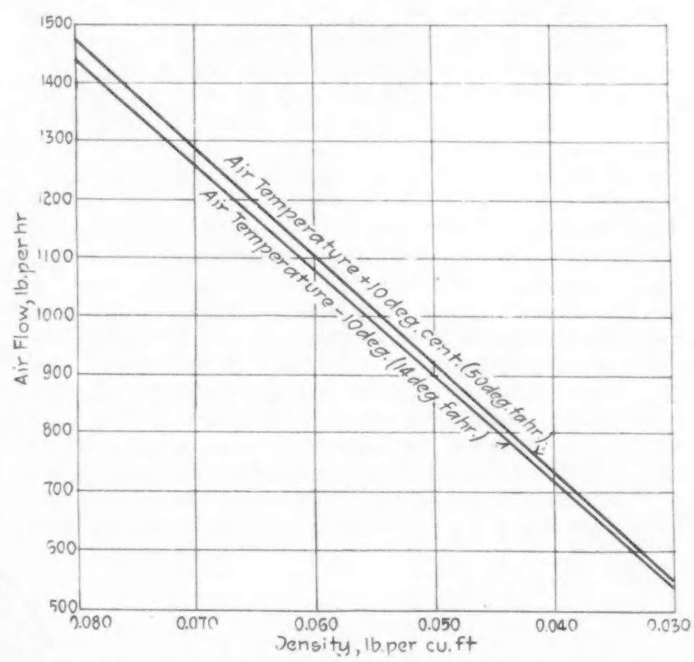


Fig. 2—Curves Showing the Relation Between Air Flow and Air Density at Different Temperatures

[1] M. S. A. E.—Mechanical engineer, automotive power plants section, Bureau of Standards, Washington.

the ratios used. The difference arising from the temperature change may cause some surprise. Since the results are plotted against air density or mass per unit volume, the increase in the quantity with an increase in the temperature obviously means a greater volume taken by the engine in a unit time. To discuss the reasons for this increase is beyond the scope of this paper. In passing, however, it may be pointed out that this answers a constantly recurring question; why, if the engine power is dependent upon the weight of charge received, does not a temperature increase cause a decrease in the power which is directly proportional to the resulting decrease in density? An inspection of Fig. 2 gives the answer that the volume of the charge taken by the engine increases with an increase in the temperature. The extent to which this volume increase offsets the density decrease determines the actual power drop.

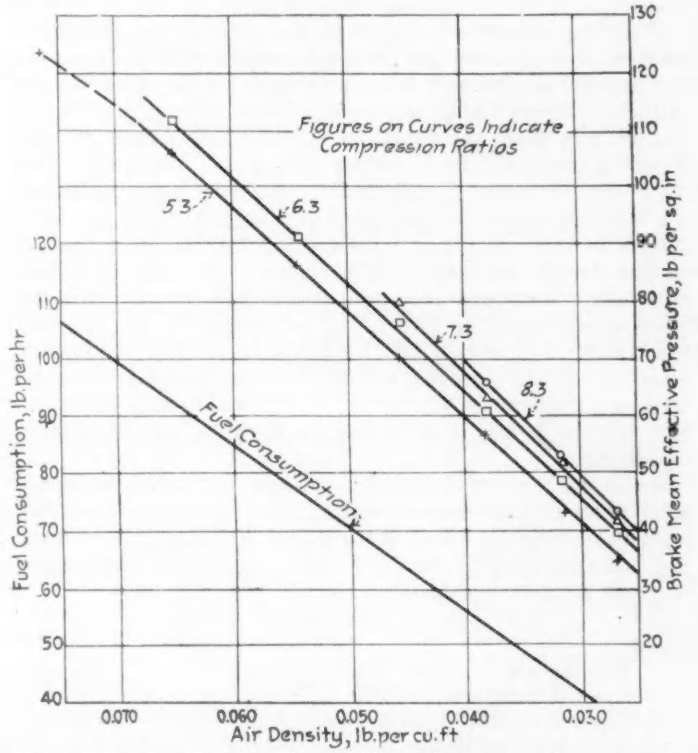


FIG. 3—CURVES OF THE BRAKE MEAN EFFECTIVE PRESSURE DEVELOPED WITH DIFFERENT COMPRESSION RATIOS AT A GIVEN RATE OF FUEL CONSUMPTION

For a comparison of engine performance on a basis of efficiency and power, the brake mean effective pressure developed with each compression ratio at a given rate of fuel consumption was plotted as shown in Fig. 3. These values were taken from curves of the type shown in Fig. 1, the rates of fuel consumption chosen being such as would be obtained with a carbureter supplying the same mixture ratio at all altitudes. Since Fig. 2 gives the air flow at all densities, it is merely a matter of division to determine the rate of fuel flow necessary to give any air-fuel ratio. It is of interest that the maximum power for these compression ratios at all altitudes was obtained with an air-fuel ratio of from 13 to 1 to 14 to 1. Fig. 3 itself needs little explanation. The lower curve gives the fuel consumption at any density, while the upper curves show the brake mean effective pressure developed from this amount of fuel with each ratio.

The absence of values for the higher compression ratios at the higher densities is due to the preignition that results under such conditions. The final temperature

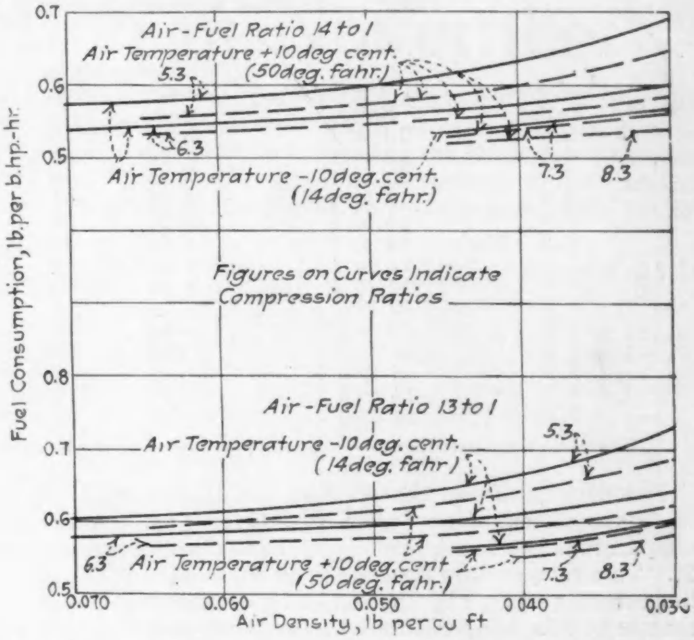


FIG. 4—CURVES OF FUEL CONSUMPTION FOR DIFFERENT AIR TEMPERATURES AND MIXTURE RATIOS

of a gas compressed adiabatically is given by the equation:

$$T_2 = T_1 r^{k-1}$$

where

T_2 = the absolute temperature at the end of compression

T_1 = the absolute temperature at the beginning of compression

r = the compression ratio

K = the ratio of the specific heat of the gas at constant pressure to that at constant volume

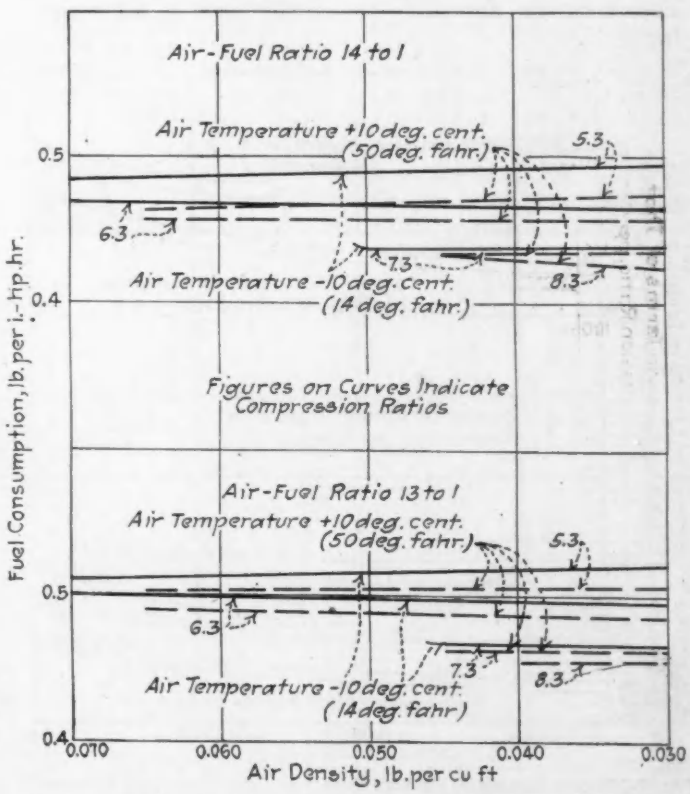


FIG. 5—FUEL CONSUMPTION IN POUNDS PER INDICATED HORSEPOWER AT DIFFERENT COMPRESSION AND AIR-FUEL RATIOS

TABLE 1—RELATION BETWEEN INDICATED THERMAL AND AIR STANDARD EFFICIENCIES

Compression Ratio	Air-Fuel Ratio	Temperature, deg. cent.	Temperature, deg. fahr.	Indicated Thermal Efficiency, per cent	Air Standard Efficiency, per cent	Indicated Thermal Efficiency in Terms of Air Standard Efficiency, per cent
5.3	13 to 1	+10	50	26.6	48.8	54.5
6.3	13 to 1	+10	50	27.5	52.2	52.6
7.3	13 to 1	+10	50	29.0	54.9	52.8
8.3	13 to 1	+10	50	29.5	57.1	51.8
5.3	14 to 1	+10	50	28.7	48.8	58.8
6.3	14 to 1	+10	50	29.4	52.2	56.3
7.3	14 to 1	+10	50	31.0	54.9	56.5
8.3	14 to 1	+10	50	31.5	57.1	55.2
5.3	13 to 1	—10	14	26.0	48.8	53.3
6.3	13 to 1	—10	14	27.0	52.2	51.7
7.3	13 to 1	—10	14	28.8	54.9	52.4
5.3	14 to 1	—10	14	27.6	48.8	56.5
6.3	14 to 1	—10	14	28.9	52.2	55.5
7.3	14 to 1	—10	14	30.6	54.9	55.8

The density of the charge does not appear explicitly in this equation. The key to its influence on the final temperature lies in its relation to the initial temperature T_1. This temperature depends upon the heat supplied to the entering charge by the hot walls of the combustion-chamber. The temperature of these walls and hence the amount of heat supplied by them is governed by the power developed. Since the power developed depends upon the density, the relation of the density to the temperature at the end of the compression is seen to be fundamental, although indirect. It must not be inferred that engine operation is impossible at these higher densities. Some fuels are known to give satisfactory operation under these conditions. The engine can be designed so as to render unnecessary development of full-load power at the lower altitudes. It seemed logical to determine first the gain that would result from increasing the compression and then to judge whether or not this gain would justify the change in fuel or the modifications in engine design necessary to employ such a ratio satisfactorily.

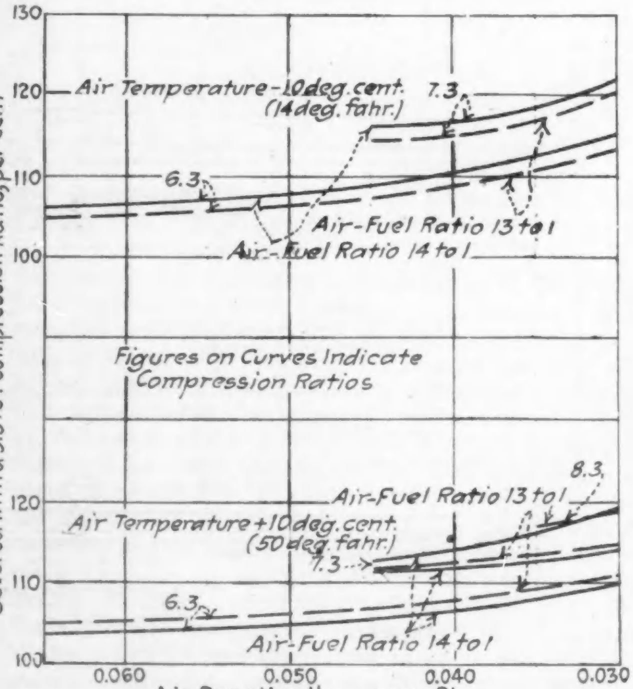


FIG. 6—BRAKE THERMAL EFFICIENCIES FOR DIFFERENT AIR TEMPERATURES AND COMPRESSION RATIOS OF 6.3 TO 1 AND 7.3 TO 1 EXPRESSED AS PERCENTAGES OF THE EFFICIENCY OBTAINED WITH A RATIO OF 5.3 TO 1

Fig. 4 summarizes the results showing the fuel consumption in pounds per brake horsepower hour for two air temperatures and two mixture ratios. The larger consumption at the greater altitudes is due to the higher percentage that the friction power there bears to the brake power. This is borne out by Fig. 5, where the fuel consumption is plotted in pounds per indicated horsepower hour. These curves suggest that the efficiency of combustion is influenced but little by a change in the density so long as the temperature is maintained constant. Temperature, on the other hand, appears to have a considerable effect. It is probable that an explanation of this will be furnished by a more complete analysis of these results. That the gain varies so greatly with the different compression ratios makes any explanation on the grounds of a change in distribution highly improbable.

As a matter of interest, average indicated thermal efficiencies and the corresponding air standard efficiencies have been tabulated and are given in Table 1. It will be recalled that the air standard efficiency for the Otto cycle is given by the expression

$$E = 1 - (1 \div r)^{k-1}$$

where

E = the air standard efficiency
r = the compression ratio
K = the specific heat at constant pressure divided by the specific heat at constant volume or 1.4 for air

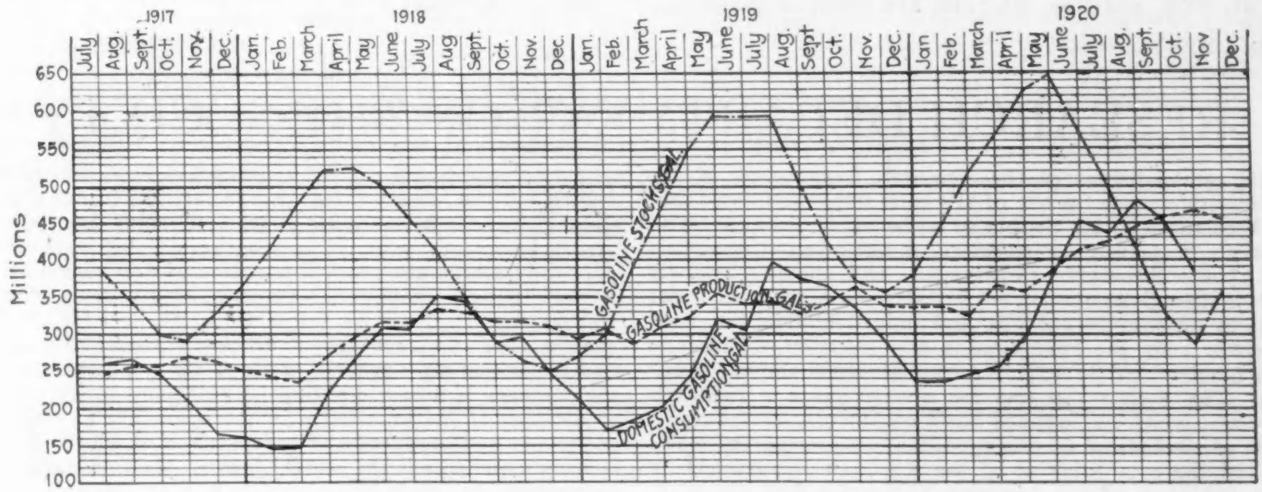
Fig. 6 presents the brake thermal efficiencies as percentages of the efficiency of the 5.3 compression ratio. It brings out very clearly that the gain ensuing from the employment of the higher ratios increases with an increase in the altitude. This latter effect is due solely to the increase in power and the resulting smaller ratio of friction to brake power. Hence, the same condition would result from supercharging or from any other method of efficiently increasing the power developed. An example will illustrate the point. Assume a brake horsepower of 50, a friction horsepower of 20 and an indicated horsepower of 70. With a fuel consumption of 0.45 lb. per i.hp-hr. there would be used in 1 hr. 31.5 lb. This makes the consumption in pounds per brake horsepower hour 31.5 ÷ 50 or 0.63 lb. If the engine be furnished an increase in the charge weight sufficient for it to develop 80 i.hp. the fuel used will be 36 lb. per hr. Such an increase will not materially change the friction and the brake power will become 80 — 20 or 60 hp. The fuel consumption now becomes 36 ÷ 60 or 0.60 lb. per b.hp-hr.,

(Concluded on page 281)

Gasoline Production in November

THE production of gasoline for the month of November, 1920, according to refinery statistics compiled by H. F. Mason of the Bureau of Mines, shows a decrease of approximately 2½ per cent from the high point of October due in part to the difference in number of days in the two months. The quantity of gasoline produced by the refineries in the United States for November was 452,642,125 gal. as compared with 465,787,745 gal. in October, 1920, and this is at the daily rate of 15,088,071 gal., against 15,025,411 gal. for October, 1920, and 11,288,919 gal. for November, 1919. The production for the month of November is the third largest since statistics have been compiled, the two previous months alone surpassing the November production. On Nov. 30 the gasoline in storage at the refineries amounted to 354,835,764 gal., as compared with 301,283,731 gal. on Oct. 31, 1920, and 378,133,185 gal. on Nov. 30, 1919.

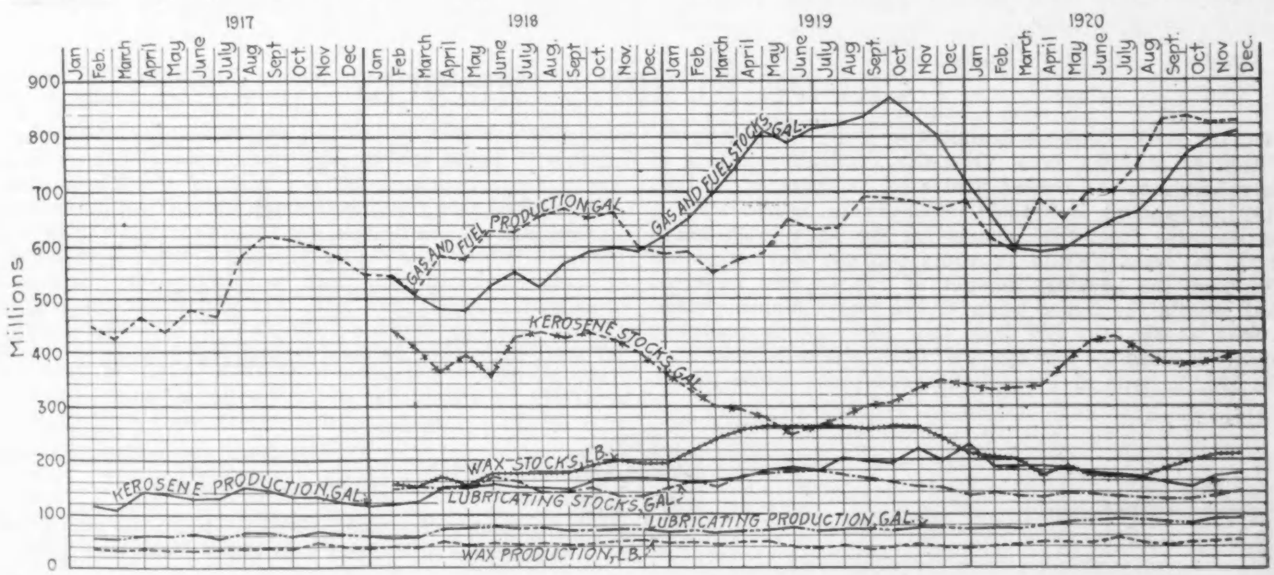
All of the minor products of petroleum showed increases in the daily average production for November over that of October, although the total quantities show declines due to the fact that October was a 31-day month



GASOLINE PRODUCTION AND STOCKS FROM AUG. 1, 1917, TO NOV. 30, 1920

PRODUCTION AND STOCKS ON HAND OF VARIOUS REFINERY PRODUCTS

	Production			Stocks on Hand		
Products	November, 1920	October, 1920	November, 1919	Nov. 30, 1920	Oct. 31, 1920	Nov. 30, 1919
Gasoline, gal.	452,642,125	465,787,745	338,667,570	354,835,764	301,283,731	378,133,185
Kerosene, gal.	214,804,177	213,742,156	214,829,910	398,991,592	383,828,239	347,070,560
Gas and Fuel Oil, gal.	822,638,305	823,114,603	663,309,510	808,802,516	799,024,084	791,052,991
Lubricating Oil, gal.	91,180,007	93,229,723	75,962,220	142,180,775	136,194,914	149,193,143
Wax, lb.	48,982,851	49,327,922	38,856,630	179,706,317	170,424,853	239,710,946



PRODUCTION AND STOCKS OF MINOR PETROLEUM PRODUCTS FROM FEB. 1, 1918, TO NOV. 30, 1920

while November had one day less. Kerosene, however, was an exception to this general rule, the total production for November amounting to 214,804,177 gal., as compared with 213,742,156 gal. in the preceding month. At the same time the stocks of kerosene increased from 383,828,239 gal. on Oct. 31 to 398,991,592 gal. on Nov. 30. The details of the production of the various petroleum products and the stocks on hand on Nov. 30 and Oct. 31, 1920, and Nov. 30, 1919, are given in the accompanying table and are shown graphically on a chart which is reproduced from the *National Petroleum News*.

In the month of November there were 326 refineries in operation with a daily capacity of 1,698,295 bbl. of crude oil, a decrease in the number of refineries of 6 and an increase in the daily capacity of 1350 bbl. as compared with the month of October. On Oct. 31, 1920, 332 refineries having a daily capacity of 1,686,945 bbl. of crude oil were in operation.

RESEARCH DEPARTMENT OF THE SOCIETY

THE establishment of the Research Department of the Society constitutes one of the most important steps that have been taken by the Society or on behalf of the automotive industry. It is fully as important as the original establishment of the Standards Department, and should obviously result in the dissemination of research data with as great benefit in an engineering way and industrially as has been consequent upon the promulgation and reduction to practice of the hundreds of S. A. E. mechanical and materials Standards. The Society has had for several years a Research Committee, which has applied itself assiduously to the clarification of methods of solving problems confronting the members, and the establishment of the Research Department is due to the work of the Research Committee and the view that it has expressed that it is essential that a well-equipped portion of the staff of the Society should devote its exclusive attention to supervisory and coordinative research work.

It is not the intention that the Society shall have a laboratory of its own or that any of its staff shall do directly research laboratory work. The program decided upon involves primarily coordination and elimination of duplication of work in various well-equipped laboratories, results from which, as well as facilities, will be available to the Society. It is becoming more and more clear to all how dependent the automotive industries are upon the work of the engineer. In turn, the engineer is wisely devoting himself more to the scientific application of his knowledge in the operation as well as of the design and production of apparatus of which the internal-combustion engine is the central factor. The problems in this connection are now international as well as national. With a number of laboratories pulling together, each will receive more of value than if it proceeded independently.

The Research Department is expected to act as a clearing-house for information and in a coordinating way on all research on subjects that are of immediate and pressing importance to the industry from time to time. Examples in this connection are factors entering into the design of radiators and fans, and proper gear tooth pressures for adequate length of life of gears in service.

The extent and province of the Research Department will be the supervision of work under the following general conditions: First, directing the work of such Government agencies as the Bureau of Standards and the Bureau of Mines in the determination of physical constants such as heat vaporization and calorific values of fuel, and to guide them in research work on general scientific engineering and industrial matters requiring standardization of elements of measurement in view of the needs of industry and commerce; second, supervising industrial laboratories in tests to settle engineering questions of immediate importance to industry; third, guiding the research efforts and programs of universities along scientific lines to definite commercial ends; fourth, gathering, indexing and digesting all available data on given subjects of dominating importance to the automotive industry, and fifth, through unity of plan and objective to eliminate duplication of research work in commercial laboratories, thus effecting vast economies.

It will be the function of the Research Committee to formulate the policies and to choose the specific researches to be undertaken, and to guide the Research Department to results of greatest industrial value. The Research Committee requests from the entire membership of the Society suggestions as to problems of great importance to the industry, and that all laboratories desiring to cooperate in the general movement be immediately placed at the disposal of the Research Committee for assignment on subjects which will be outlined later.

CRUDE RUBBER IMPORTS

ACCORDING to figures compiled by the Rubber Association of America, New York City, the importations of crude rubber into the United States for the year ended Dec. 31, 1920, amounted to 221,080 tons. These figures show a slight decrease from the imports for the year 1919, which were 231,511 tons. While February was the shortest month of the year the greatest amount of rubber was imported in that month, the figure being 32,994 tons. March ranked next with 31,650 tons and from then the imports gradually dropped, reaching the low figure of 6448 tons in November.

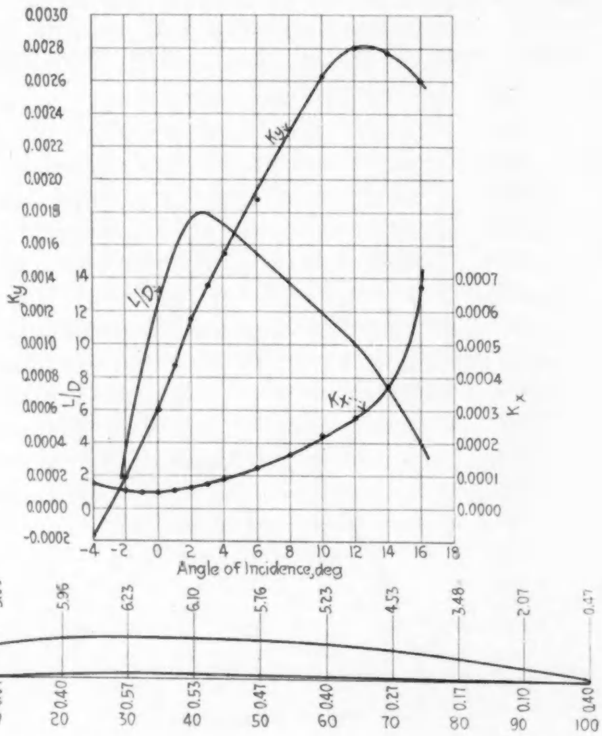
The 196,972 tons of Plantations grade constituted practically 89 per cent of the imports, while Para rubber ranked next with 18,391 tons or slightly more than 8¼ per cent of the total. Approximately 92 per cent of the Plantations rubber reached this country through the port of New York. A comparison of the figures for 1919 and 1920 shows that the African rubber was the only grade which was imported to a greater extent in 1920 than in 1919 and the increase there was only about 16 per cent. The imports of the Plantations grade were approximately the same in both years, while that of the Para rubber declined from 27,058 tons in 1919 to 18,391 tons in 1920.

Some Experiments on Thick Wings with Flaps

By C. D. HANSCOM[1]

ANNUAL MEETING PAPER — *Illustrated with* CHARTS

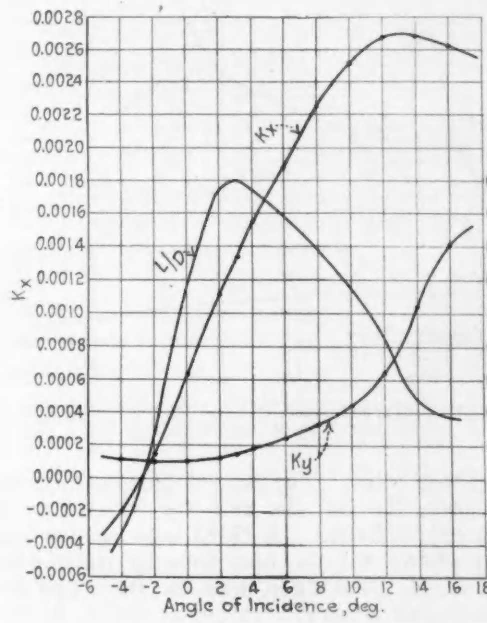
THE subject of thick wings has been taking on a constantly increasing importance in aeronautical discussions for several years. Since the war, with the urgent necessity for instant production removed, aeronautical engineers have been turning to practical experiments. It should, therefore, aid in general aeronautic development if all information on the subject is made available for common use. The Glenn L. Martin Co. has recently had tests made in the wind tunnel of the Massachusetts Institute of Technology in the endeavor to obtain more data on the action of wings with flaps. Both front and rear flaps were employed, and the results showed several interesting features. When it was decided to have the experiments made, no sections were at hand which possessed all of the qualifications needed. It was especially desirable that the movement of the flaps should produce minimum discontinuities of surface. This requirement at once limited the choice of sections. Ultimately four base sections were adopted and the new wings developed from them.

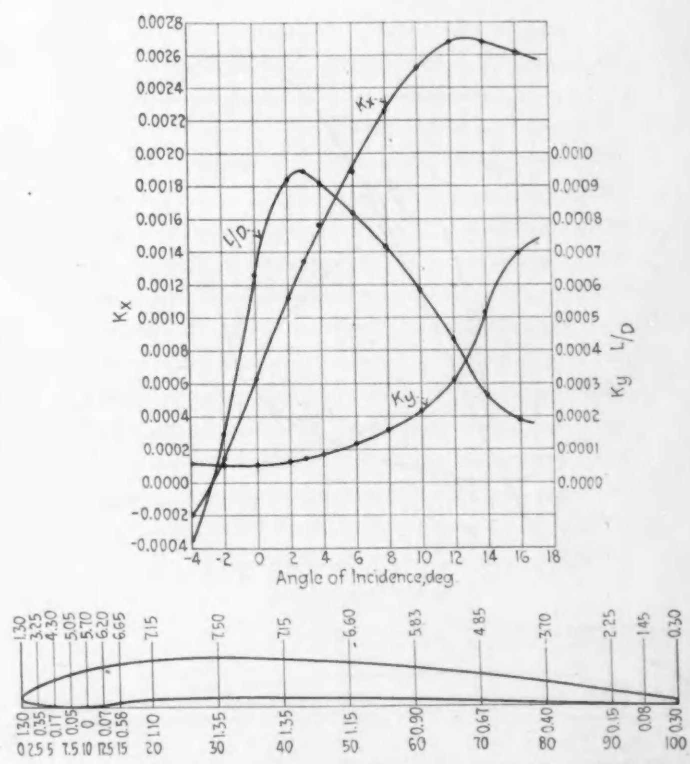


Kx, *Ky* AND *L/D* CHARACTERISTIC CURVES AND SECTION ORDINATES FOR THE D1 WING SECTION

FOUR MASTER SECTIONS

The first, and most logical, choice was the USA 27. The wing developed from this section eventually proved





Kx, *Ky* AND *L/D* CHARACTERISTIC CURVES AND SECTION ORDINATES FOR THE H1 WING SECTION

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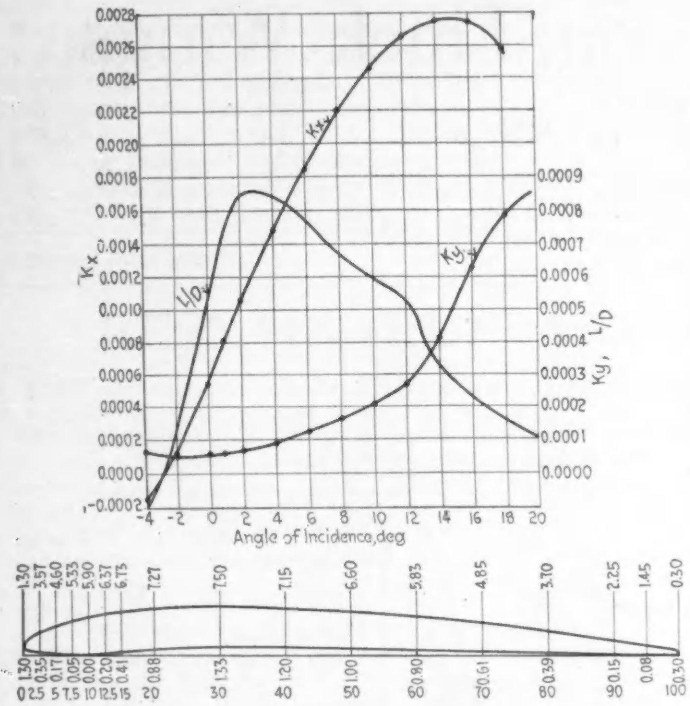
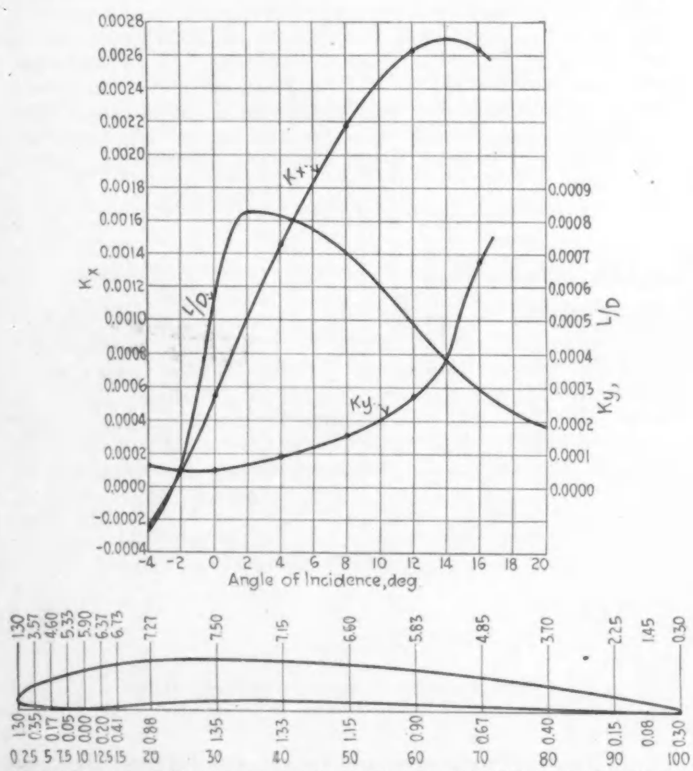


Kx, *Ky* AND *L/D* CHARACTERISTIC CURVES AND SECTION ORDINATES FOR THE H3a WING SECTION

the best of those tried. The second base section was a wing of my own, the H1, the data for which has never heretofore been published. A third base section, which is now being shown for the first time by permission of its designer, G. M. Denkinger, was the D1. The fourth master section was a composite curve which resembled no wing in particular.

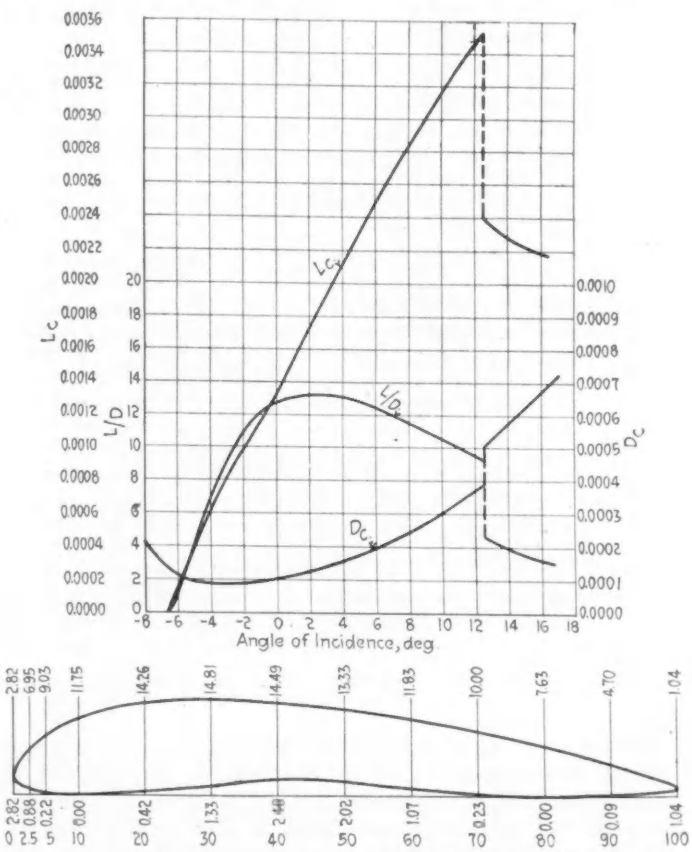
From these master curves, six new wings were designed. The USA 27 was thickened appreciably, and



Kx, *Ky* AND *L/D* CHARACTERISTIC CURVES AND SECTION ORDINATES FOR THE H3b WING SECTION

minor modifications were made in its form. The new section was called the No. 2. The D1 was uniformly increased in camber, by a percentage ratio, producing the Glenn Martin No. 5. The H1 was modified in three ways. The rear upper surface was raised in all cases to allow more room for the flap. This injured the qualities of the wing to a considerable degree. One wing designated as No. 1 was then made having a sharp trailing edge; another, No. 6, with a blunt trailing edge, and a third, No. 4, with a blunt trailing edge and a practically flat under camber. The fourth master section was modified only slightly, having been designed especially for the purpose. This latter was called No. 3.

The six models and the sockets were made at the Massachusetts Institute of Technology by its employes. The ordinates given in the different illustrations were scaled from sections of these models, and therefore represent to a good degree of accuracy the actual sections tested. The models were all 3 x 18 in., and the wind velocity was always 30 m.p.h. The tests themselves

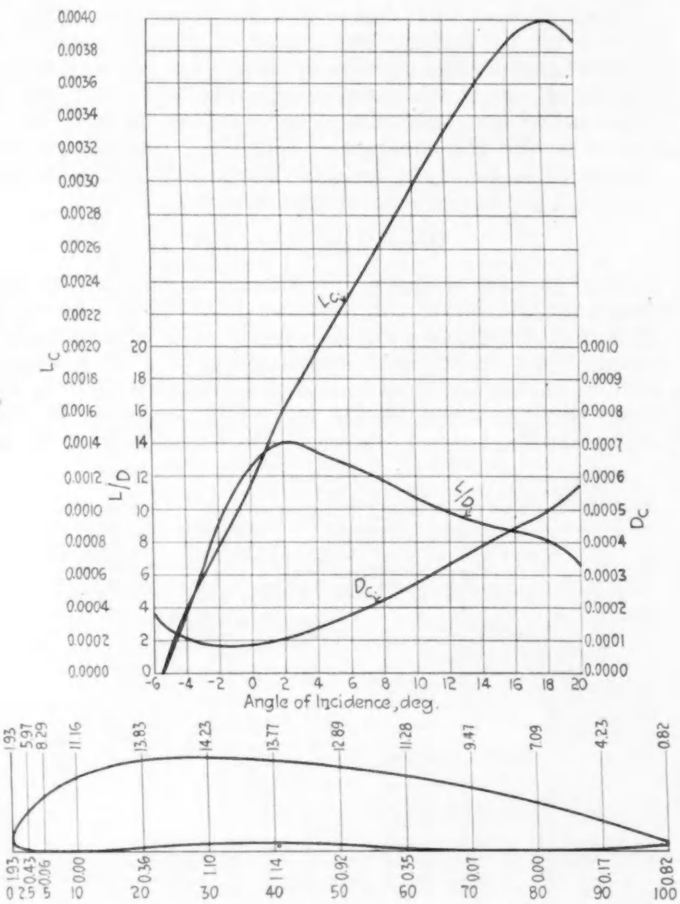


Dc, *Lc* AND *L/D* CHARACTERISTIC CURVES AND SECTION ORDINATES FOR THE GLENN MARTIN 1 WING SECTION

were under the personal direction of Prof. E. P. Warner. I was also present, and at the balance in most cases.

The special qualities which led to the selection of the four master sections deserve attention. The USA 27 was not thick enough, nor did it have a sufficiently high lift for the purpose of which it was needed. It was, however, by far the best thick section known. It was therefore only logical that it should be chosen. The form of the Glenn Martin No. 3 was arbitrarily adopted, the purpose being to combine low drag at small angles with good lift at higher angles. The *L/D* was better than for any of the other sections, but the lift proved unsatisfactory. The choice of the D1 and H1 wings was the result of private tests made in 1919. The D1 was de-

signed as a high-speed section. It actually proved to be one of the best known wings, of practical shape, at a lift coefficient of from 40 to 50 per cent of the maximum. In this range, and in fact everywhere above it, the D1 is much superior to the RAF 15. Below 36 per cent, at high speeds, it is inferior, although not greatly so. No change was made in the section in stepping all ordinates up by the same ratio to obtain the Glenn Martin No. 5. The H1 was designed to attain good efficiency at large angles, and if possible, a high lift. The high lift did not

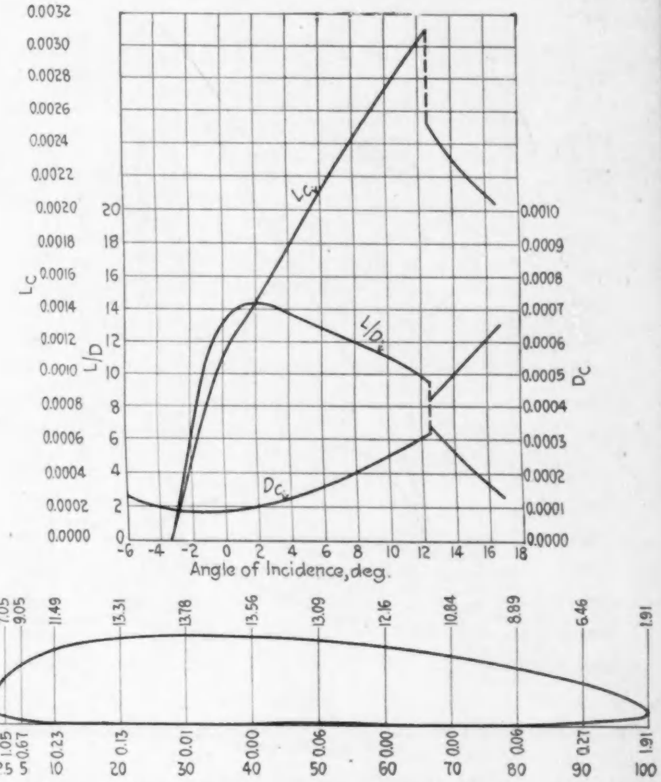


Dc, Lc AND *L/D* CHARACTERISTIC CURVES AND SECTION ORDINATES FOR THE GLENN MARTIN 2 WING SECTION

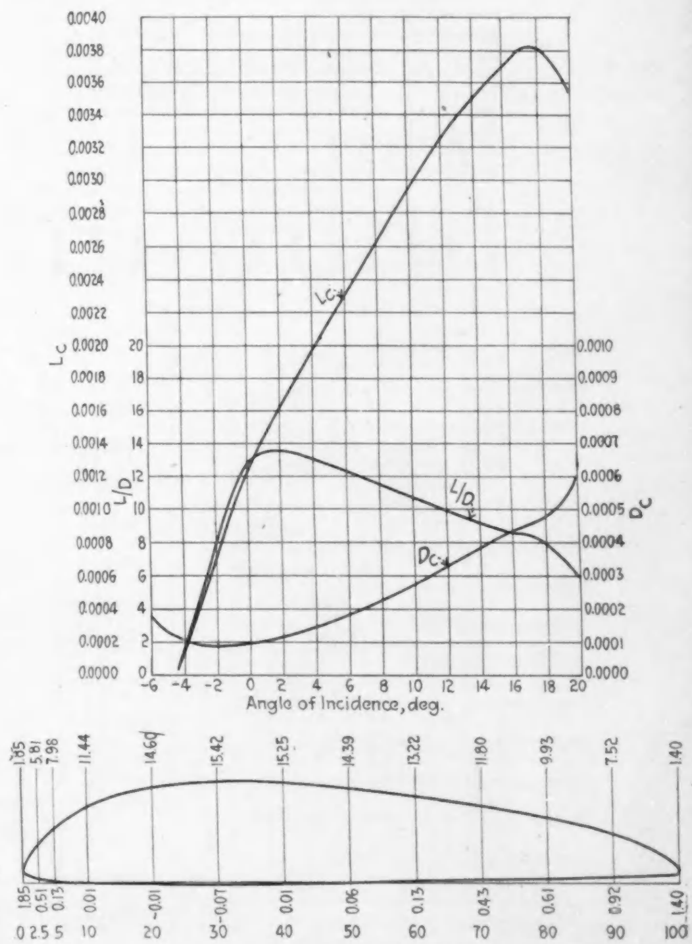
materialize, but the L/D at climbing speeds varying from 66.6 to 75 per cent of the maximum L_c is exceptionally good, being 16 to 15.[2] Two attempts were made to improve the lifting qualities of this section, by thickening the nose, but they failed to accomplish their object. The wings thus produced, H3a and H3b, are practically the same except that H3a has a very slight bump on the lower surface at 50 per cent of the chord. The difference in the characteristic curves is, therefore, noteworthy. H3a and H3b, however, merely indicated the advisability of making the modifications in H1 as small as possible.

Unfortunately, H1 had to be changed to a considerable degree to permit flaps to be employed. The rear lower surface had to be bulged down to accommodate the hinges and operating mechanism, and to relieve the sharpness of the break which would occur when the rear flap was

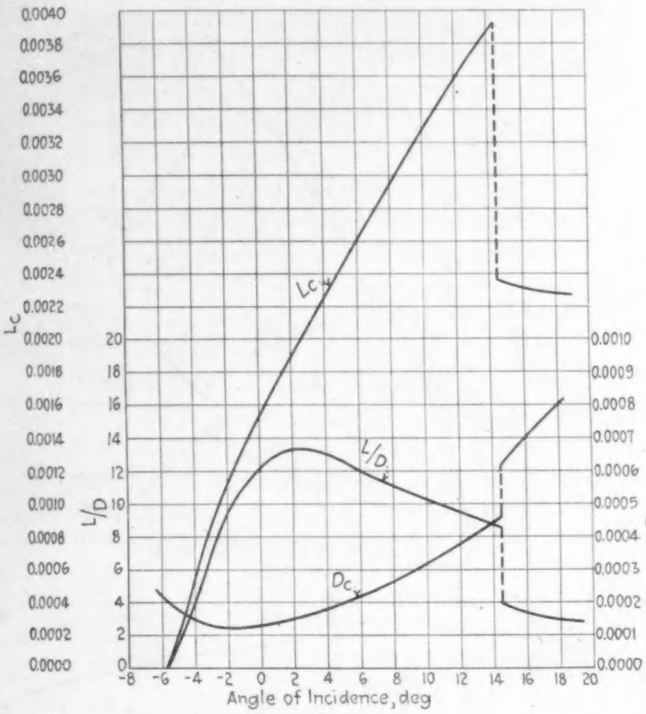
[2]Two sets of characteristic curves are shown for the H1. Those having the maximum L/D of 17.9 are the standard Massachusetts Institute of Technology tests. The others, with a maximum L/D of 18.9, show the same data corrected for spindle interference to permit of a direct comparison with the tests performed at the National Physical Laboratory, Teddington, England.



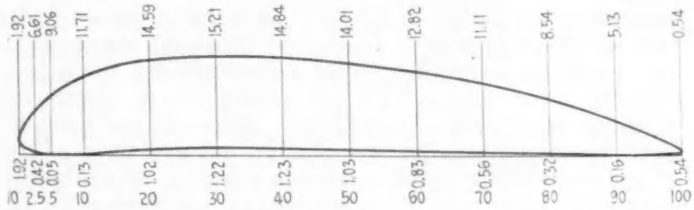
Dc, Lc AND *L/D* CHARACTERISTIC CURVES AND SECTION ORDINATES FOR THE GLENN MARTIN 3 WING SECTION



Dc, Lc AND *L/D* CHARACTERISTIC CURVES AND SECTION ORDINATES FOR THE GLENN MARTIN 4 WING SECTION



Dc, Lc AND *L/D* CHARACTERISTIC CURVES FOR THE GLENN MARTIN 5 WING SECTION

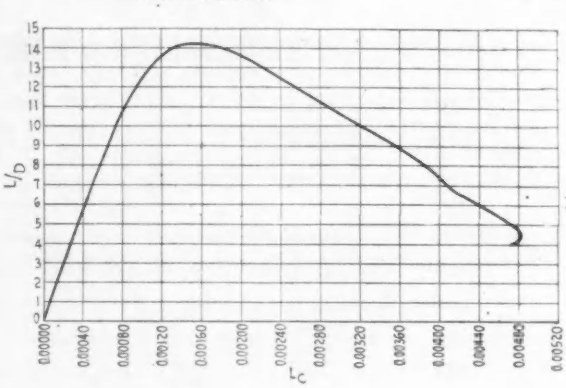


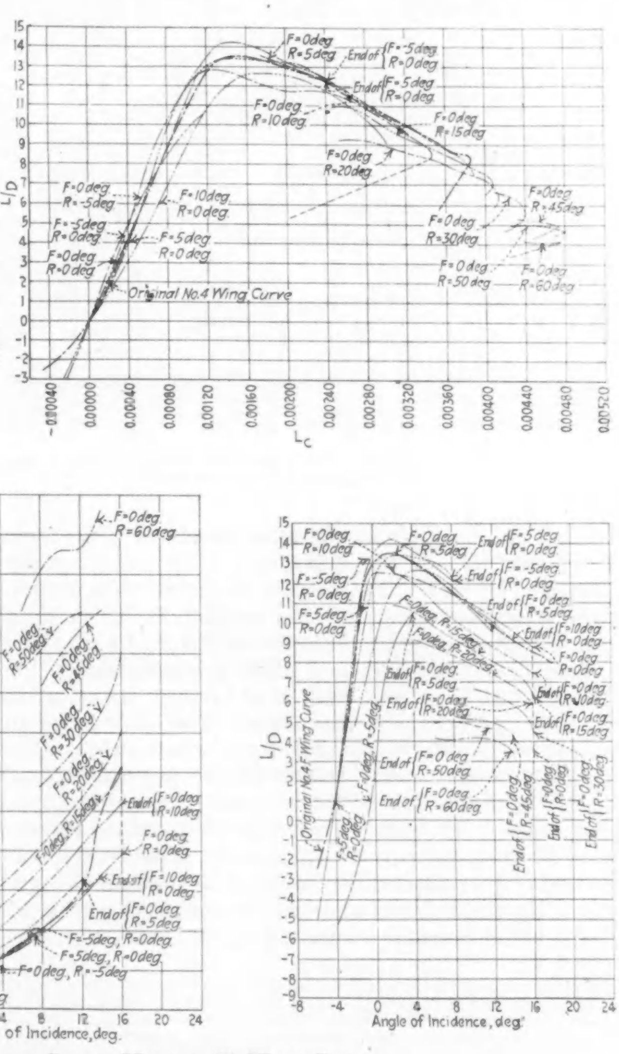
SECTION ORDINATES FOR THE GLENN MARTIN 5 WING SECTION

pulled down. These changes proved one point in the original design. Efficiency at high angles was obtained in the H1 by making the angles of trail, approximate angles made by the upper and lower rear surfaces to the chord, as nearly the same as possible. In other words, the trailing part was thin. The new Glenn Martin wings based on the H1 apparently lacked any exceptional efficiency at large angles because of the thickening of the trailing part out of proportion to the rest.

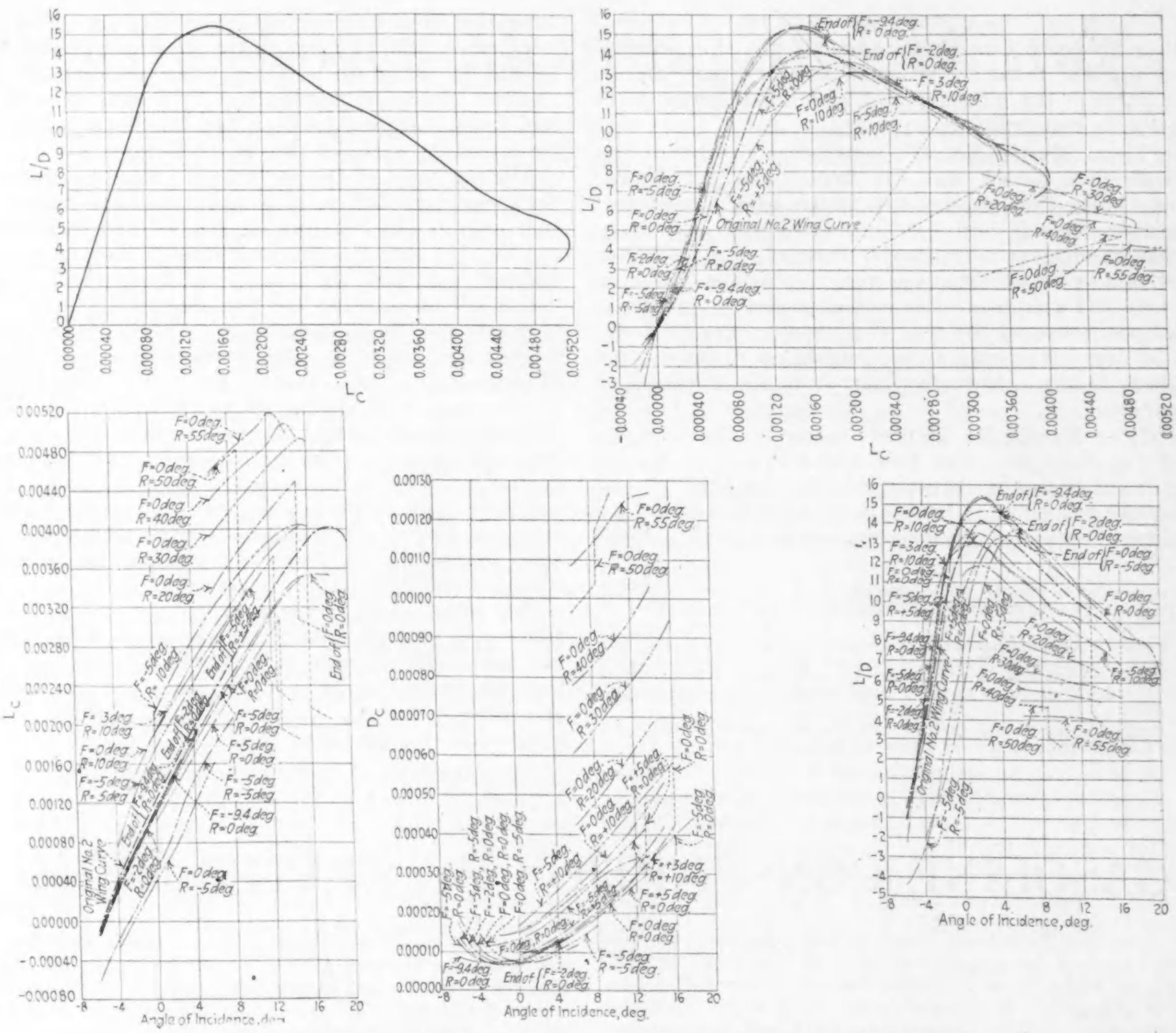
NEW WING DESIGNS

The six new wings are sufficiently described by the characteristic curves and tables of data. It may be noted that discontinuities occur in several cases at the burble point. This phenomenon is not unusual for thick wings, and, of course, disappears at higher velocities. It is obvious that the Glenn Martin No. 2 and the Glenn Martin No. 4 are the best of the six. The Glenn Martin No. 5





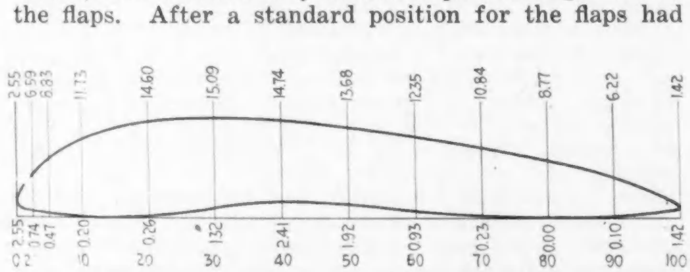
COMBINED CHARACTERISTIC CURVES OF THE GLENN MARTIN 4F WING SECTION



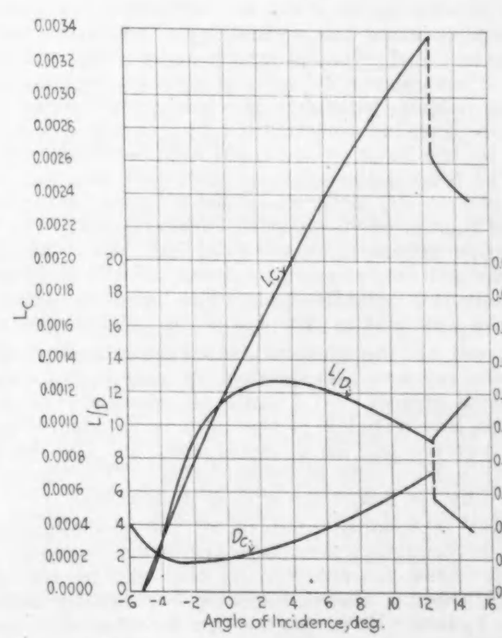
COMBINED CHARACTERISTIC CURVES OF THE GLENN MARTIN 2F WING SECTION

would undoubtedly have shown a higher lift in proportion as the velocity increased, but its lower efficiency ruled it out.

Sections Nos. 2 and 4 were therefore tested being hinged at 15 and 70 per cent of the chord length. The hinges were approximately 0.03 in. from the bottom surface, and the hinge-plates were sunk flush with the surface. The slight hollows at the hinge-plates and the cracks between the flaps and the main part of the wing were filled with plasticine. The sections were retested, and the errors of alignment noted. It is, of course, impossible to cut a wing in this manner and duplicate the original results, unless the model is metal. The errors, as indicated by a study of the model and the curves obtained, seemed due chiefly to lack of perfect alignment of the flaps. After a standard position for the flaps had



SECTION ORDINATES FOR THE GLENN MARTIN 6 WING SECTION



Dc, Lc AND *L/D* CHARACTERISTIC CURVES FOR THE GLENN MARTIN 6 WING SECTION

been determined, the other tests were run at accurate angles with respect to this standard; but the standard varied slightly from the original wing. Since the envelope curve is the ultimate goal, this minor error, while annoying, is relatively unimportant.

The Glenn Martin No. 4F, which was the No. 4 section with flaps added, was run first. The test demonstrated clearly that at very low angles of lift coefficient a negative angle is best for both front and rear flaps; but that at any speed ordinarily reached, the front flap only should be raised from the normal position. At high values of lift the front flap could profitably be in its normal position, and the rear flap should be down about 45 to 50 deg. It is only at the burble point and beyond that there is any noteworthy gain from the lowering of the rear flap.

The Glenn Martin No. 2F gave better results than the No. 4F, as expected. The conclusions drawn in regard to the use of flaps are almost identical. An angle of —5 deg. for the front flap is beneficial at all values of lift up to the burble point of the original wing. At very small lifts, the front flap can be raised even to —10 deg. with additional gain. In this latter region, also, the rear flap should be lifted to —5 deg. As the burble point is reached, the front flap apparently should come to 0 deg., and from there on the rear flap should be brought down by successive stages to about + 55 deg.

The qualities of the wings with flaps, as indicated by these tests, remain to be considered. The maximum lift increased 25 per cent for the No. 4F and 29 per cent for the No. 2F, over the original wing. These new maxima,[3] 0.00484 and 0.00516, constitute the highest lift coefficients yet attained as far as I am aware.[4] The drag at this extreme lift is, however, very high. It is interesting to note that for the No. 2F the L/D is 15.1 at 25 per cent of L_c maxima, and 8.4 at 11 per cent.[5] These values of L_c correspond to speeds of twice and three times the minimum respectively. It would therefore appear that for racing machines the use of a wing with flaps is highly desirable. For heavy weight-carrying planes, the drag would be high at low speeds; and the performance would resemble that of the Fokker-Junkers, which seems to be slow in pulling up from the ground, but climbs well when a good flying speed is attained.

The effect of an increase in speed and scale is uncertain, since experiments on thick wings with flaps have not been made. There is, however, no reason to believe that the wing characteristics would not improve to an appreciable extent. In any event, full-flight tests can soon settle the question.

[3] If a correction is applied for the reduction of chord and area with the flaps at large angles, L_c would approach 0.00575 in the case of the No. 2F.

[4] The largest value i have noted elsewhere is that recorded for the RAF 19 in Report and Memorandum No. 648, published by the Advisory Committee for Aeronautics (Great Britain). That report records $C_1 = 0.93$, or $L_c = 0.00474$. The Handley Page apparently only reached $C_1 = 0.8$, or $L_c = 0.00408$.

[5] The corresponding values for the RAF 15 obtained from National Physical Laboratory test are 14.5 and 7.7 per cent.

GASOLINE CONSUMPTION BY STATES IN 1920

THE American Petroleum Institute has compiled information showing the quantity of gasoline consumed in 1920 by 12 States which have oil inspection and where such information is available. In certain States all gasoline inspected is fuel gasoline, while in others it is impossible to estimate the proportion consumed by motor vehicles, except to indicate that the bulk of the gasoline consumed is for that purpose.

Without attempting to make any allowance for consumption by other agencies and without including in the compilation any estimate of consumption by motorcycles and motorboats, the figures shown indicate an average consumption of gasoline per vehicle, passenger cars and motor trucks, in the States where gasoline consumption figures are available of 452.1 gal. on the basis of the 1920 automobile registration figures. The total registration of passenger cars and motor trucks as of Dec. 31, 1920, was 8,887,572 cars, according to preliminary figures of *Automotive Industries*. On the basis of an average consumption of 452.1 gal. per vehicle, the indicated gasoline consumption by motor vehicles in 1920 was approximately 4,018,000,000 gal. The gasoline output of United States refineries in 1920 was about 4,870,000,000 gal.

In Arkansas all the gasoline inspected is fuel gasoline; therefore, the average consumption per car of 404.7 gal. is probably about correct. In Florida all gasoline inspected is fuel gasoline, but included in the total is the quantity consumed by motorboats. It is noted that the figures show Florida with a high rate of consumption. This figure may be influenced by the heavy use of cars by tourists.

No attempt at detailed analysis of the above figures is made, as it is recognized that there are several elements that might easily throw off calculations one way or the other. For instance, there is always difficulty in obtaining accurate registration figures. However, the figures obtained from the various States on gasoline consumption in 1920 constitute an actual record and make an unusually true basis for arriving at average gasoline consumption by motor vehicles. Estimates of the average annual consumption per car of motor vehicles in the United States have varied from 400 to 550 gal.

The following table gives the quantity of gasoline consumed in 1920, the number of cars registered and the average consumption per car for the States for which this information is available:

State	Gasoline Consumed, Gal.	Number of Vehicles	Average Consumption Per Vehicle, Gal.
Alabama	48,000,000	74,637	643.1
Arkasas	23,911,079	59,082	404.7
Colorado	51,452,244	128,951	399.0
Florida	53,735,278	57,000	942.7
Kansas	117,096,600	265,396	441.2
North Carolina	73,960,000	140,860	525.1
Ohio	273,411,650	616,800	443.3
Oklahoma	62,991,167	204,300	308.3
Oregon	44,900,669	103,790	432.6
South Carolina	41,225,067	92,818	444.1
South Dakota	41,000,000	122,000	336.1
Tennessee	57,841,190	101,852	567.9
Total	889,524,944	1,967,486	452.1

There is a decidedly different rate of consumption for passenger vehicles than for motor trucks. The average of 452.1 gal. obtained from the Institute's figures is inclusive of both passenger vehicles and motor trucks. Results from the experience of various fleet owners indicate that the average consumption of gasoline by motor trucks is about 1000 gal. annually, and the preliminary figures of the National Automobile Chamber of Commerce show approximately 900,000 motor trucks registered at the end of 1920. Accepting these estimates on the basis of the gasoline consumption figures shown above for the various States, the indicated annual consumption per passenger car is 390.3 gal.

Farm Power Meeting and Dinner

THE Sixth Annual Farm Power Meeting of the Society, held at Columbus, Ohio, on Feb. 10, during the week of the National Tractor Show, resulted in the presentation of much information of technical and economic value. More than 200 members and guests attended the professional sessions and the dinner. The various subjects discussed were of a very timely nature in this day of intensive study of agricultural, industrial and financial conditions from the National standpoint. The United States Department of Agriculture had just announced that the value of farm crops of 1920 and of farm animal products and animals sold and slaughtered was $19,856,000,000, this being $5,105,000,000 less than the corresponding figure for 1919. Despite the drop in prices the total value of farm products for last year was about 100 per cent greater than it was in 1914, which was a record breaking year; the value of the 1920 crops was more than 80 per cent greater than that of 1914 or 1913, 1913 having been a banner year. The Department of Agriculture estimates that the value of all crops in the United States was 2 per cent higher in 1920 than the average value of the 5 war-years. In this connection it is understood that the farmers of this country own 2,500,000 passenger cars and motor trucks, and that 60 per cent of the automobiles produced last year were purchased in agricultural districts. In emphasizing the fact that the American farmer cannot get along without those tools that are necessary for efficient production in his field of endeavor, L. J. Taber, master of the Ohio State Grange, stated that, whereas the American farmer purchases 45 per cent of the manufacturing output of this country not exported, his dollar has decreased in relative value recently 56 per cent.

Plowing Speeds

E. A. Johnston, the vice-president of the Society representing tractor engineering, presided at the technical sessions. D. L. Arnold, chairman of the Society committee that has been making an exhaustive study of plowing speeds reported on its current work. He made it clear that less power is required to plow with three bottoms than with two bottoms at the higher speed necessary to cover the same acreage in a given time; furthermore that at the same speed the cost of the three-bottom plowing is less. The power required increases with the speed, apparently regardless of the type of soil, that is, in about the same proportion in sand, stubble or 7-year old sod. The cost becomes less as the speed increases, and about proportionally with all soils. Mr. Arnold feels that while certain fundamental facts with regard to plowing speeds have been determined definitely, much further research is necessary in connection with them. He advocates the use of the term "rate of plowing" or "plowing velocity" in expressing plowing speed, inasmuch as with changing conditions high speed of today may be considered low speed tomorrow. Professor Davidson, of Iowa State College, confirmed the general deductions made by Mr. Arnold, stating that the variation in the depth of plowing has more influence than speed on the amount of power required. He said that about 14 factors are involved in determining the draft of a plow, the principal increase in draft being due to the effort necessary to turn the furrow slice. He expressed the opinion that the shape of the moldboard does not affect the draft and that there is an opportunity to change the design of plows so that they will have less surface in contact with the soil.

Chairman Johnston said that the draft of a 14 in. plow varies from 200 to 1800 lb., and that, as there is no one best plowing speed for all conditions, it will be necessary to standardize on perhaps three different speeds. Major O. B. Zimmerman said that the committee's experiments are of vital importance as it is essential to secure economic gain, however slight this may be, by the institution of scientific methods in farm-power operations. Every detail should be gone into carefully with a view to attaining the best possible results with a tractor having an assumed life of 7 years. Granting that the cost of the tests being made will amount to $50,000, the work will nevertheless result in a net saving in comparison with determining the right plowing speeds by empirical methods.

Tractor Belt Work

John Mainland, chairman of the Committee on Pulley Widths and Speeds, mentioned the 5, 6, 7, 8 and 9 in. belt widths which had been recommended for standard at the last meeting of the Standards Committee of the Society, no recommendations as to standard lengths being made. The current recommendations would if accepted result in a modification of the present pulley and belt width standards by replacing the 4 in. belt width with 5 in. and adding the 9 in. It is felt that a 4 in. belt is not practical for tractors from the driven-machine standpoint. According to the recommendation of the committee, the pulley is to be at least ½ in. wider than the belt to be used on it.

Mr. Mainland is convinced that all tractor engines should be equipped with governors, as these are necessary in operating belt-driven machinery with tractors and it is advisable to use tractors in as many farm operations as possible.

Authoritative data on belt and pulley speeds employed in farm work in this country are scarce and the committee has a strenuous task ahead of it to secure and collate an adequate amount of such data. All economic losses, such as belt slippage, must be reduced to the lowest possible minimum.

Anti-Freezing Solutions

The subject of anti-freezing solutions, which is of yearly recurring interest, is of such importance in the tractor field that a special committee of the Society was established for the purpose of making a thorough study of the use of certain mineral oils and of mixtures of salts or fluid chemicals with water to lower the freezing point of the mixture, with a view to making specific recommendations of constructive value in the operation of tractors. Major Zimmerman, who is chairman of this committee, made a progress report at the Columbus meeting. He said that it may be necessary for the committee to undertake research in a way analogous to that followed in the case of lubricants and fuels. Disregarding the mineral oils, the cooling medium should be cheap and easily obtainable, non-corrosive, not cause electrolytic action, have a boiling point not too high above that of water, not freeze much above — 20 deg. fahr., have low viscosity, be a minimum fire hazard, have high thermal conductivity and

possess other characteristics which Major Zimmerman enumerated. Concerning the use of salts like calcium chloride, it is stated that the hope that the average user would make his own solution is futile. The committee feels that the use of salts for preventing freezing is undesirable in view of the almost certain electrolytic action involved therein. The free boiling off of alcohol means uncertainty as to the nature of the solution in the engine. However, a mixture of 1 part amyl alcohol to 39 parts of water freezes at — 20 deg. fahr., and unlike ethyl and methyl alcohol has a boiling point of 264 deg. fahr. Its intoxicating effect far exceeds that of ethyl alcohol. With regard to the group of mineral oils, the committee feels that the arguments against these for use as anti-freeze fluid are based in large part on lack of accurate information. Tractors have been cooled successfully for many years with heavy oils during all seasons. The committee will endeavor to secure complete technical data on the characteristics of the mineral oils in question.

John A. Secor, pioneer engineer of the Advance-Rumely Co., said that his company had used oil for cooling for 12 years and equipped 30,000 tractors with oil-cooling means adapted to all climates and atmospheric temperatures. The packing in the pump gland requires replacement usually about once each season. The cooling oil is circulated by a centrifugal pump driven from the engine camshaft. Ordinary commercial Winter Black oil is used. The oil should be non-freezing and have an initial boiling point of not less than 500 deg. fahr. Radiators designed for water cooling are not ordinarily suitable for oil cooling. The general characteristics of Winter Black are as follows:

Pour Test, deg. fahr.	20
Viscosity at 104 deg. fahr., sec.	181
Viscosity at 210 deg. fahr., sec.	46½
Flash Point, deg. fahr.	345
Fire Point, deg. fahr.	385
Range of Boiling Points, deg. fahr.	550 to 750

On account of the viscosity of the oil at freezing temperature, it is customary to add kerosene to the Winter Black in the winter for adequate pumping action. As warm weather approaches, the kerosene evaporates gradually. The average temperature of the cooling oil as discharged from the cylinder jackets is from 175 to 200 deg. fahr. Winter Black does not deposit tarry material at its working temperatures. Mr. Secor made it plain that only suitable oil of known characteristics should be used for cooling. Engine lubricating oil is not suitable.

Dr. D. R. Harper gave an outline of the research work on radiators that has been done at the Bureau of Standards. He said that while the scientific work that has been done here and abroad provides much information, there are few data suitable for use in preparing specifications for radiators for automobiles and tractors, although under known conditions some of the results obtained in testing aircraft radiators are applicable. The heat transfer varies as the 0.8 power of the air-flow, the flow of air through the radiator being less than the velocity of the radiator through the air. It is necessary to know the actual rate of air-flow through the radiator core. The matter of the course of travel of air after it passes through the radiator has received too little attention. The specific heat of the cooling medium is of course important, but its thermal conductivity is so great that there is practically no difference in the temperature of the liquid and of the metal with which it is in contact. The Bureau of Standards has done only preliminary work in the study of anti-freeze solutions. Dr. Harper said that ordinary ethyl alcohol has a corrosive effect on copper and brass.

Nebraska Tractor Tests

Prof. Oscar W. Sjogren gave an exposition of the tractor tests conducted and the equipment used in furtherance of the provisions of the law of the State of Nebraska regarding the sale of tractors there. His presentation of the subject was clear and comprehensive and very closely followed. The law mentioned provides in substance that tractors sold in Nebraska shall be tested and passed upon by a board of three engineers under State University management, that those selling tractors shall secure from the State Railway Commission a permit that is issuable after the respective stock models of tractor have been tested as aforesaid. The official test includes a 12-hr. limbering up run, a brake-horsepower test at rated load and speed for 2 hr., a brake-horsepower test for 1 hr. at various loads to show fuel consumption under variable load and speed control of the governor, a brake-horsepower test at maximum load for 1 hr., a brake-horsepower test at one-half load for 1 hr., a drawbar horsepower test at rated load for 10 continuous hr., a maximum drawbar-horsepower test, and an investigation of the turning radius, the effectiveness of the brakes and of other apparently important features. The length of the test varies from 28 to 58 hr. The general nature of the testing equipment was described by L. W. Chase at the 1920 Annual Chicago Meeting of the Society.[1]

With regard to weaknesses developed in the tractors by the runs, Professor Sjogren said that some of the changes made during the tests were due to a lack of knowledge on the part of the operators, but that in some cases defects had been overlooked at the factory. He believes that exhaustive factory tests of tractors should be made by a corps of men having no part in the design work. Most of the trouble encountered in the cooling systems was due to the fan belts, although some cylinder-head water-passages were too small. In a few instances a change of carbureters resulted in increase of power output. Professor Sjogren is of the opinion that close control of injected water is necessary; also that there is a conspicuous need for further development of air-cleaners. Some of the governors installed were very ineffective.

Pulleys of the detachable type gave trouble, due to the short shaft mounting, with only one bearing usually. Some pulleys were mounted in such a way that the belt dragged on the steering-knuckles of the front wheels. In other cases it was impossible to line the engine up in a short time.

Of the 68 machines which appeared for test 39 went through without making any changes, while 29 made changes as follows: 11 failed to make their original rating, 7 of these have changed their ratings; 6 changed their rated engine speed; 11 changed some item of equipment; and 3 withdrew after the preliminary test.

Professor Sjogren advocates the rating of tractors according to a standard. Of the 60 tractors which completed the test, 51 had a manufacturer's rating for belt horsepower in excess of the rating that was formerly a standard of the Society, namely, 80 per cent of the horsepower that the engine is guaranteed to deliver at the pulley continuously for 2 hr., the engine being in good condition and properly operated at its rated speed. Of the tractors tested only four failed to develop as much belt horsepower as was specified in the respective manufacturer's rating.

[1] See The Journal, January, 1920, p. 44.

With reference to drawbar horsepower, 44 of the 60 tractors were rated in conformity with the former S.A.E. Standard for tractor drawbar horsepower, namely, 80 per cent of the horsepower that the tractor is guaranteed to develop at the drawbar continuously for 2 hr., the tractor being in good condition and properly operated at the rated engine speed, and on ground sufficiently firm to give the traction wheels a good footing. Two tractors did not develop as much horsepower at the drawbar as the manufacturer's rating specified.

The former S.A.E. Standards mentioned above were cancelled last year upon recommendation of the Tractor Division at the meeting of the Society held in June. There had been considerable adverse criticism of the drawbar-horsepower-rating standard, on account particularly of the belief that in regular procedure it is not feasible to make tests "on ground sufficiently firm to give the traction wheels a good footing, firm sod being preferable," as set forth in the former standard. It was argued that the basis of tractor rating should be the engine displacement, and the Tractor Division made in June 1919 a specific recommendation to this effect, which was not accepted by the Standards Committee. The tractor horsepower formula developed by the 1919 Tractor Division, this being based on engine displacement as stated, is considered a commercial rather than an engineering formula. An extended discussion of the whole matter was reported in THE JOURNAL[2] and as a matter of general information the displacement formula was included in the old Vol. I of the S.A.E. HANDBOOK, page 20b, together with data relating thereto. This matter is not contained in the revised Vol. I of the Handbook recently issued, for the reason that it is intended generally speaking that henceforth this volume shall include only S.A.E. Standards and Recommended Practices.

Professor Sjogren said that in the tests the consumption per brake-horsepower-hour was about the same with kerosene as with gasoline, and that the greater crankcase oil dilution consequent upon the use of kerosene did not make the cost of the use of kerosene as much as that of gasoline. He felt that it was superfluous to mention that it is inadvisable to use kerosene in a gasoline engine.

In the discussion of wheel lugs, Major Zimmerman said that these probably constitute the weakest point in the knowledge of tractor design today; that while a plow should be designed to give the maximum disturbance of the soil with a minimum expenditure of energy, the opposite is true in the case of the tractor, this making the matter of wheel design very important. Professor Magruder said that a special study should be made of power transmission losses. The amount of power lost between the engine shaft and the drawbar sometimes amounts to many times what is gained by increased fuel economy.

CARBURETION OF ALCOHOL

A. W. Scarratt made a valuable contribution in the form of a report on intensive experimental work done recently by the Minneapolis Steel & Machinery Co., with which he is associated, in developing an engine to burn alcohol economically and efficiently. Pointing to the increasing demand from abroad for American farm power equipment, he said that the greatest obstacle confronting tractors exported from this country is the use in an economical and satisfactory manner of fuels available in foreign countries. In Cuba, Brazil, Argentina, Chile, Porto Rico and Venezuela petroleum fuels are very expensive, while alcohol is comparatively cheap. The types of gasoline engine usually produced in this country for installation in tractors will operate on alcohol but in an inefficient manner.

It is difficult to vaporize alcohol; it ignites at a considerably higher temperature than gasoline, is only six-tenths as rich in heat units as gasoline by weight and is 15 to 20 per cent heavier by volume. Commercial alcohol contains approximately 10 per cent of water by weight. Its range of distillation temperature is from 158 to 175 deg. fahr. Mr. Scarratt said that more heat has to be applied to alcohol than to kerosene mixtures for good operation. In his experiments two types of carbureting and manifold methods were used, one a special Twin-City Holley system, and the other the Twin-City vaporizer previously described in THE JOURNAL.[3] The brake-horsepower developed with alcohol was more than equal to that ordinarily developed with gasoline or kerosene for the same expenditure in British thermal units. A compression of 110 lb. gage was finally settled upon as giving the most satisfactory results. The engine used was a 16-valve four-cylinder 4 x 6-in. Engine starting is somewhat more difficult when using alcohol, on account of the greater cranking effort necessary and the fact that air at ordinary temperatures does not vaporize the alcohol sufficiently to make a good combustible mixture. Satisfactory starting was accomplished by redesigning the starting-crank and using a 4-to-1 mixture of alcohol and gasoline.

Mr. Scarratt said that very generous provision for heating the alcohol fuel charge must be made, he having found that utilization of the entire exhaust heat was necessary. In addition to heating the alcohol, the air was heated to 210 deg. fahr. The temperature of the ingoing charge, for good carburetion and economical operation, should not be less than 100 deg. fahr. Good distribution of the mixture to the cylinders is essential when using alcohol at high compression. The intake-manifold gas velocity, at full load, should not be less than 9500 ft. per min. average.

The fact that alcohol vaporizes at a practically constant temperature is of marked advantage in engine operation, once the engine is properly warmed-up. Mr. Scarratt found practically no carbon residue resulting from the use of alcohol; the valve-seats were in surprisingly good condition after long hard runs. No pre-ignition was experienced. He believes that if the automotive industry demands the manufacture of alcohol for fuel purposes, it will head the list of automotive fuels eventually.

Mr. Secor said that in some parts of the world alcohol is the cheapest engine fuel available; that it had been reported that tractor engines are operated in Esthonia on alcohol at a rate of consumption of 0.735 lb. per hp-hr. with 85-lb. gage compression. Mr. Johnston said that while it is feasible to secure a thermal efficiency of 0.65 lb. per hp-hr. with kerosene and of 0.53 with gasoline, there is room for much improvement in fuel economy under average operating conditions.

TREND OF TRACTOR DESIGN

Mr. Johnston gave some very illuminating information by showing some moving pictures of an experimental two-plow tractor designed for use with many kinds of farm operating equipment, the various implements being readily attachable and detachable without the use of tools of any kind, such as hand socket-wrenches. It appeared that the development which Mr. Johnston demonstrated

[2] See THE JOURNAL, August, 1919, p. 188.

[3] See THE JOURNAL, August, 1920, p. 123.

was a revelation of tremendous importance to the tractor industry, agriculture and the Nation. The essential feature of the apparatus is the transmission of the power directly from the engine to the implement, eliminating the transmission of power through a ground wheel. This, Mr. Johnston said, causes less trouble in operation and has other advantages.

Mr. Johnston stated that the tractor will succeed in the degree that it is made profitable to those using it, and that the whole matter is a question of tractor design. With regard to the relative merits of wheeled and track-laying tractors, he is of the opinion that each of the types is satisfactory in its field. The two great essentials of the tractor are reliability and economy. The operator cannot be expected to make many, if any, adjustments; a minimum of attention must be required. The stresses to which such elements as gears and sprockets are subjected should be low enough to assure long life. A high-grade product is requisite.

As an elementary principle, tractors should be equipped with a power-takeoff. On most farms many of the extensively diversified operations are of such a nature that power cannot be applied to them with heavy tractors. The production per man must be increased. This problem is of an engineering nature and is solvable by the proper application of automotive power.

The cultivator equipment that Mr. Johnston showed will cost and weigh, he said, 75 per cent as much as a horse-drawn cultivator. He exhibited a 14-ft. cut mower which weighed about the same as a 6 or 7-ft. cut horse-drawn mower. It is estimated that with the tractor equipment one operator can mow hay at the rate of 4 acres per hr. The 12 to 14-ft. hay raker should increase the capacity per man 300 to 400 per cent. Another implement shown gathers and carries 8 to 12 shocks, this constituting a sufficient capacity to keep a small separator supplied, equalling the work accomplished by three teams and six men. Hay or other material such as cornstalks which are difficult to handle by hand are lifted by derrick. The 10-ft. binder and harvester can be produced, it is said, at 60 per cent of the cost of a horse-drawn harvester. Another of the apparatus is a 10-ft. binder with automatic shocker. The 14-ft. header weighs and costs half as much as the corresponding horse-drawn implement, and the field can be opened up without tracking down the grain. The husking is done in the field. A two-row snapper, picking ears from stalks without husking them, was shown. There is also auxiliary apparatus for doing spraying or for pumping water in case of fire, direct from the engine.

The principle upon which Mr. Johnston has proceeded is that it is possible to design a machine that will replace on a farm of from 100 to 150 acres all the seven to nine horses usually employed thereon. The main fact to be kept in mind is that each horse itself consumes the product of five acres. It is estimated that the cost of operation of the power equipment is 60 per cent of that of the horse-drawn. While there is no doubt, Mr. Johnston said, that the tractor for heavy belt and drawbar work, which is being developed rapidly, is profitable, some such power equipment as that he showed must be produced for use on small farms, that is those of 50 acres or less.

In connection with electric lighting and starting for tractors, Mr. Johnston confirmed the opinion that there is always a demand for such conveniences. He feels, however, that most designers do not favor the installation of electric starting apparatus on tractors now, in view of the doubt as to the ability of storage batteries to withstand satisfactorily tractor operating conditions. Considerable night work is done with tractors on the Pacific coast, lighting being had with acetylene as a source or from constant-voltage generators without a battery. In some instances tractors are operated continuously for 22 hr. for six days of the week.

Dinner Addresses

Professor Davidson presented the view, contrary to those ordinarily expressed, that there are now a sufficient number of men resident on farms in this country, and that the main things to be borne in mind are increasing the production efficiency per man and the comforts, conveniences and attractions on farms. There are 8000 less farms in Iowa than there were 10 years ago. In India 90 per cent of the population live on farms. But this is not evidence of a healthy condition, the standard of agriculture being of course low.

Professor Davidson said that he had been reliably informed that there are millions of acres of unused land in China, and averred that what is needed is efficient agriculture. The strength of a country depends upon the status of its rural life. The country has always replenished the cities. A high capacity for production means a high standard of the individual. It is possible now for one man to produce 30 times as much in the way of farm product as he could produce in 1830. Twenty-five to thirty million horsepower is used in various forms in agriculture. Included in the equipment on the farms in this country are 42 per cent of the buildings of the Nation. We have 200,000,000 acres of unused cutover land available. For the purpose of comparison, Professor Davidson pointed to the fact that there are 35,000,000 acres of land in Iowa. He said that 80,000,000 acres are reclaimable by draining, and 150,000,000 more by irrigation. With regard to fertility, he said, in connection with agriculture being one of the largest fields for engineering, that the soil of the Eastern portion of the United States can if necessary be brought back by known methods to a state of real productivity. The average farm practice in this country is not anywhere near the best that is feasible. Farm engineering has developed on a probational basis, the farmer not having been able to pay the engineer adequate fees. Capacity farming means of course capacity buying by the farmer.

Mr. Taber, master of the Ohio State Grange, said that the automotive engineers can do more for civilization than any other body of men of equal number in this country. The progress in agriculture that has been attained is the result of the work of the automotive engineer. Manufacturing genius developed America. Power generation and farm machinery are inextricably interwoven.

Speaking on behalf of over 100,000 Ohio farmers, Mr. Taber said that there is no "non-partisan" radicalism, socialism or communism among them. The farmer is loyal and will not be radical unless the financial-manufacturing interests are blind to rural conditions. The farmer is not on a strike but awaiting the economic adjustment that is necessary. He cannot be forced to buy, but he cannot do without the things that are essential for efficient production. A better understanding between the people of the country and of the towns is requisite. By cooperation between the engineer and the farmer on grounds of fair agreement, great progress can be made.

(*Concluded on page* 287)

S. A. E. Exhibit at the Columbus Tractor Show

THE cut-away engine shown in the foreground demonstrated the reduction to practice of many of the more than 40 S.A.E. Standards established for use in the design and construction of automotive engines of the internal-combustion type. Of the more than 200 S.A.E. Standards and Recommended Practices a larger number are applicable in the fabrication and installation of engines than in any other assembly unit of motor vehicles. Nearly 100 of the S.A.E. Standards are suitable for use in the design and construction of tractors and many of these are being applied in this connection more and more widely.

SOCIETY EXHIBIT AT THE SIXTH ANNUAL NATIONAL TRACTOR SHOW ILLUSTRATING THE EMPLOYMENT OF S.A.E. STANDARDS IN THE CONSTRUCTION OF AN INTERNAL-COMBUSTION ENGINE

COMPRESSION RATIO AND THERMAL EFFICIENCY OF AIRPLANE ENGINES

(*Concluded from page* 268)

a 5 per cent decrease. With a supercharger furnishing the increased charge, the efficiency of the supercharging device would enter the calculation making the net gain less. If, on the other hand, the increased power were obtained by an increase in the compression ratio, the gain would be more because there would be a lower fuel consumption in pounds per indicated horsepower hour with the higher ratio. In other words, with an increase in the compression ratio there is a gain in the indicated efficiency that is peculiar to this method of increasing power and, in addition, a gain in the brake efficiency that is common to all methods of increasing power.

Intake Flow in Manifolds and Cylinders

By P. S. Tice[1]

Annual Meeting Paper *Illustrated with* Photographs

SEVERAL months ago, in the execution of a certain piece of work, it became evident that the air flows in the passages generally employed were not nearly so simple and orderly as our small knowledge of such matters had led us to expect. There was every evidence

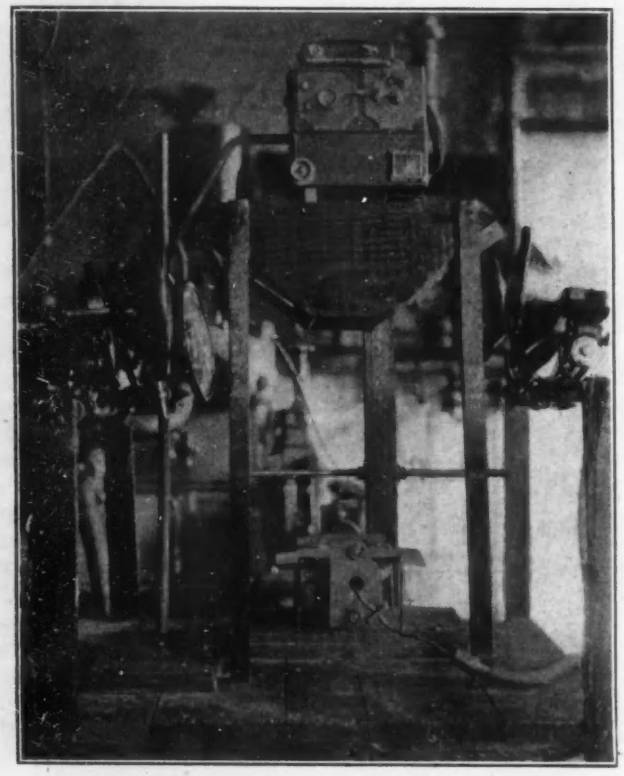


Fig. 1—The Arrangement of the Camera Which Was Used to Make the Photographs of Manifold Conditions

of the existence of eddies, whorls and impacts of considerable magnitudes at various points in the passage. After experimenting a bit, it was decided to stop guessing, and devise a means of making visual observations

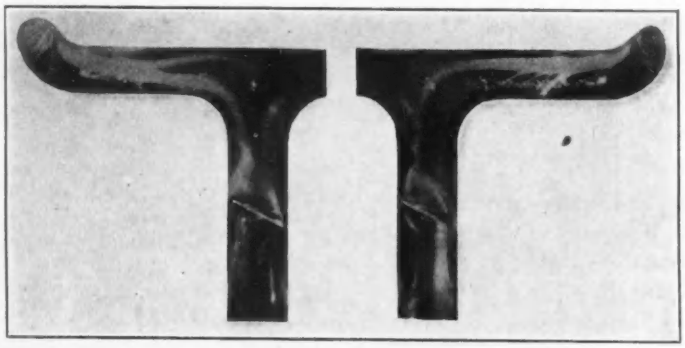


Fig. 3—Conditions Existing in the Manifold with the Throttle Open Slightly

of the paths followed by the several portions of the air stream.

One of the passages being considered was half-sectioned in a plane about which the passage was symmetrical; that is, a plane containing the axes of the several parts of the passage. This method of making the cut causes the least disturbance of the flow lines in the sectioned member, as compared with those in the complete passage.

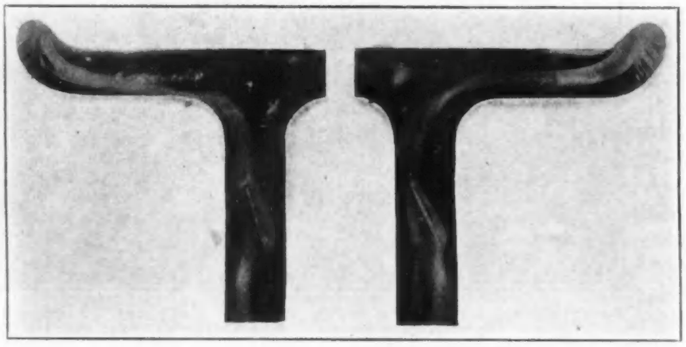


Fig. 4—Manifold Conditions with the Throttle Approximately Half Open

A flat glass plate was then cemented on to complete the half-passage. With the outlet end of such a passage connected to an engine intake, any sort of flow encountered

[1] M.S.A.E.—Engineer in charge of the carbureter division, Stewart-Warner Speedometer Corporation, Chicago.

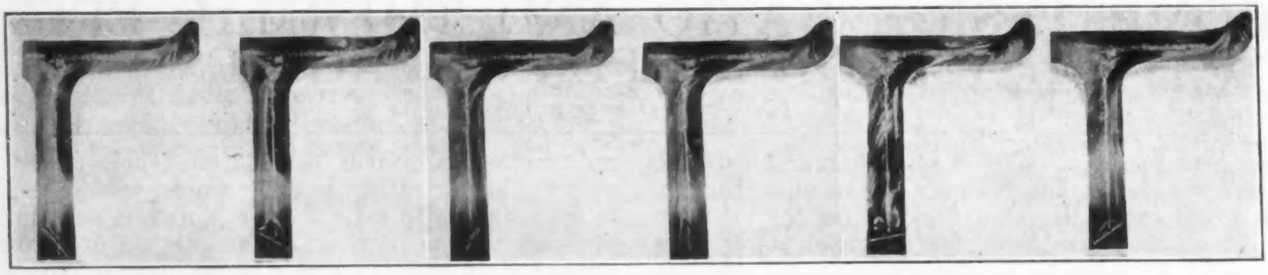


Fig. 2—Photograph of a Manifold Having a Comparatively Long Riser Showing How the Flow in the Riser Is Changed by Varying the Angular Position of the Throttle

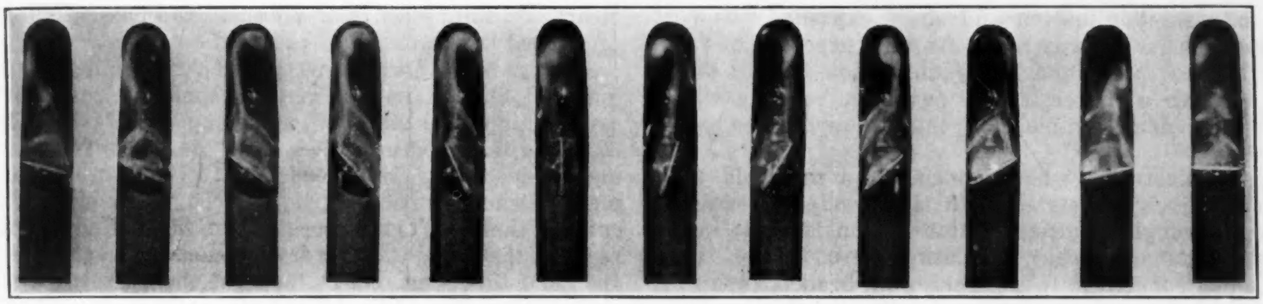


Fig. 7—Photographs Taken While the Throttle Is Rotating Through 180 Deg.

in engine practice can be reproduced. It then only remained to introduce a comparatively non-volatile liquid that readily wets glass, such as gasoline, with the entering air, to cause a tracery of fine sharply defined lines

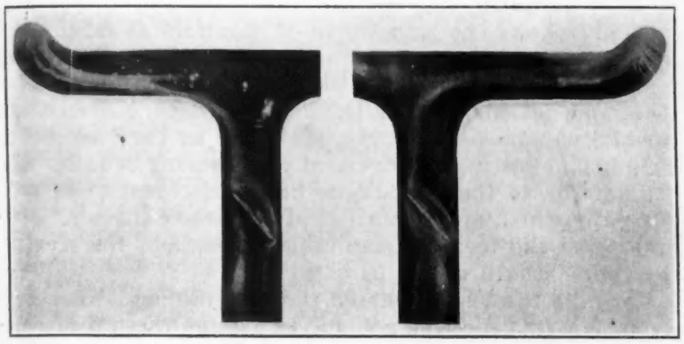


Fig. 5—Opening the Throttle Still Further Has Not Produced Any Material Change in the Manifold Conditions

on the glass. These follow the air-flow lines faithfully and permit one to make valuable studies of passage flows. The application of the information obtained with this method of observation has proved that the tracery seen on the glass sufficiently indicates the flow lines followed in the middle plane of the complete full-section passage.

Following the completion of the work for which the set-up was made one of my assistants suggested that we apply the same method of observation to typical intake manifolds and cylinder combustion-chambers. The illustrations in the paper represent a portion of these latter observations.

Fig. 1 shows the photographic set-up used for recording purposes. A 3¼ x 4¼-in. Graflex camera is supported to point directly down upon the glass wall of the half-passage. A framework supports two rectangular mirrors which are used to reflect the light from a group of spotlights, in lines nearly normal to the glass on which the tracery appears. A black paper mask, cut to the outline of the passage, keeps the images of the lamps off

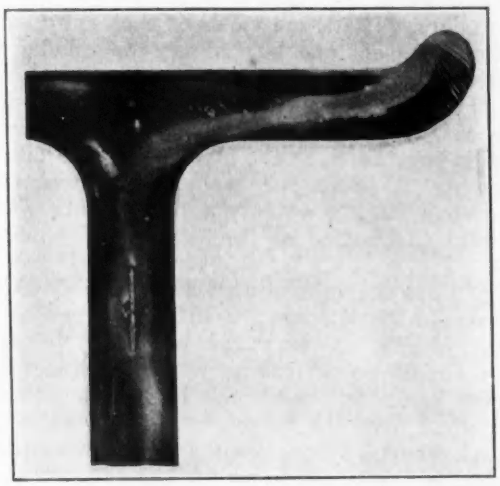


Fig. 6—A Wide-Open Throttle Resulting in Ideal Flows in the Two Intake Branches

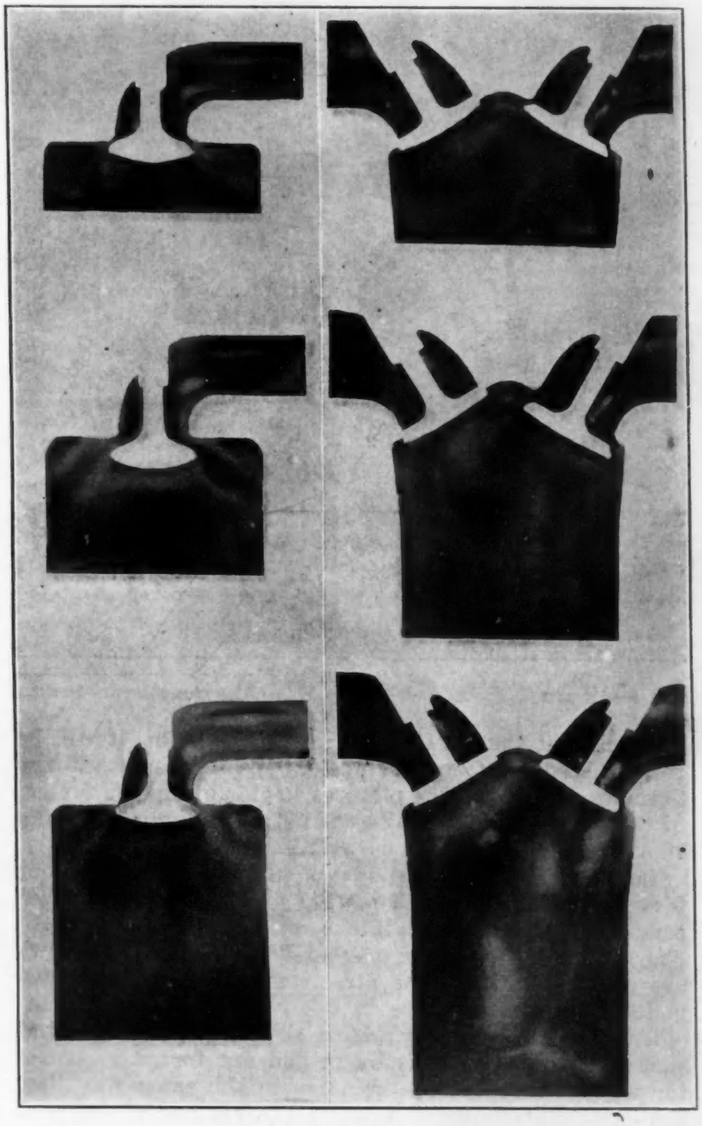


Fig. 8—Intake Flow in Two Typical Valve-in-the-Head Cylinders

the camera screen. The reflection and refraction of the light at the fine liquid streams on the glass, cause their positions to be defined sharply on the camera screen. It has been found that, while complete detail is obtained

with intense illumination and short exposure, the best general purpose records result from an exposure of from 5 to 10 sec., with reduced illumination. This latter method gives a flatter, softer negative, but one which shows the general and more important flow lines to better advantage.

Fig. 2 illustrates what happens in a manifold with a comparatively long riser. In this group the throttle is taken through a half-revolution by considerable increments. The significant revelation here is the small effect upon conditions in the horizontal branch, resulting from a complete reversal of the throttle angular position, even though such change materially alters the flow in the riser. The whirling set up in the stream as it enters the outlet bend should be noticed and also that the major portion of the fuel hugs the lower wall of the branch,

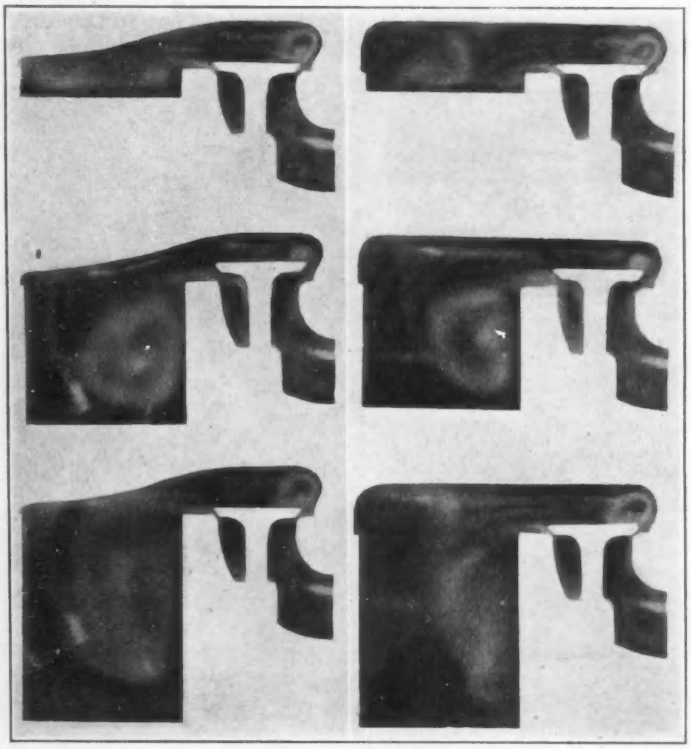


FIG. 9—INTAKE FLOW IN TWO FORMS OF L-HEAD COMBUSTION SPACES

beginning at the tee itself. This latter point, it will be remembered, was well shown by W. S. James at the Summer Meeting. The pictures in this group are typical of the photographic results with strong illumination and short exposure.

Less intense illumination and an exposure of about 5 sec. were used in making the next set of records of conditions in a typical intake with a short riser. In Fig. 3 and the others immediately following, the views are grouped to show the direct effects of throttle valve deflection upon the flows in the two branches. In considering each of these views, it should be borne in mind that the liquid filaments lie in and are forced to travel toward the low-pressure regions, in the same way that the earth's atmosphere flows to the regions of lowered pressure. Thus, the light streaks and areas in the illustration represent the low-pressure or high-velocity portions of the stream, and the dark places those regions of relatively high pressure. In Fig. 4 the throttle is opened slightly farther, and the reason why liquid distribution to the branches is sometimes imperfect is shown very clearly by the presence of liquid in the non-active outlet of the tee in one case and not in the other.

In Fig. 5 the throttle is opened still farther, with no material change in the general condition. A further cause of unequal distribution among cylinders is shown to reside in the whirling set up in the bends forming the manifold outlets. It is seen that in the two ends of the pipe the concentrations of liquid occupy somewhat different positions. Furthermore, when the whirling charge reaches the usual siamesed valve-ports, the chances are about 20 to 1 that one cylinder of the pair will receive more of this concentrated fuel stream than the other. It seems that a useful control of this phase of distribution would result, in any one case, from altering the lengths of the curved portions at the manifold outlets. Fig. 6 finishes this group, and shows open-throttle which, of course, results in perfectly identical flows in the two branches, provided the carbureter is shaped and mounted so as to permit it.

Fig. 7 shows the same form of manifold as that just preceding, but sectioned through the riser in a plane at right angles to the outlets of the tee. At the top of each view, one is looking directly into a branch. Also, the throttle spindle lies in the same plane as the branches. This is an effective arrangement for insuring equality of distribution to the tee outlets, but it also results in an energetic whirling or rotation of the whole stream, beginning at the tee, and persisting throughout the whole remaining length of the passage.

Here the throttle is rotated through 180 deg., to show completely its deflecting action. In making these records, the liquid was introduced in a thin film traveling along the surface of the glass; while in the others it was merely sprayed into the air-stream. This was done to bring out more clearly the behavior of the air-stream at the throttle valve. It is interesting to note how coming events cast their shadows before them at the upstream side of the throttle. At open-throttle the entering edge of the 1/16-in. thick valve is enveloped in a region of high pressure possessing a curiously alluring but apparently empty form; while at small angles from the open position, this region has sections suggesting a thick airfoil. The flow, with respect to its rotational direction in the branches, is very unstable at open-throttle, first whirling in one direction and then the other, resulting, in this photographic record, in what appears to be a symmetrical figure. These exposures had a duration of from 9 to 10 sec.

In Fig. 8 we have intake flow in two typical valve-in-head cylinders. The three views of each cylinder are intended to represent the beginning, the middle and the end of the suction stroke. Note particularly the forms and locations of the whorls at small clearances, and how they die out, so far as any concerted internal motion in the mass is concerned, as the piston is moved out. From this showing, it seems reasonable to suppose that this heterogeneous motion would not be amounting to much as a useful turbulence at the end of the compression stroke.

In Fig. 9 are corresponding views made in two forms of L-head combustion spaces. The enlarged and more persistent whorls, as compared with the valve-in-head cylinders, should be noticed as well as the fact that the combustion space in which the height is non-uniform being greatest over the valves, causes a greater portion of the total charge to participate in the whirling. The latter form is the superior performer in an engine, and an exaggeration of it might well be investigated.

Can Automobile Body Weight Be Reduced?

By Charles A. Heergeist[1]

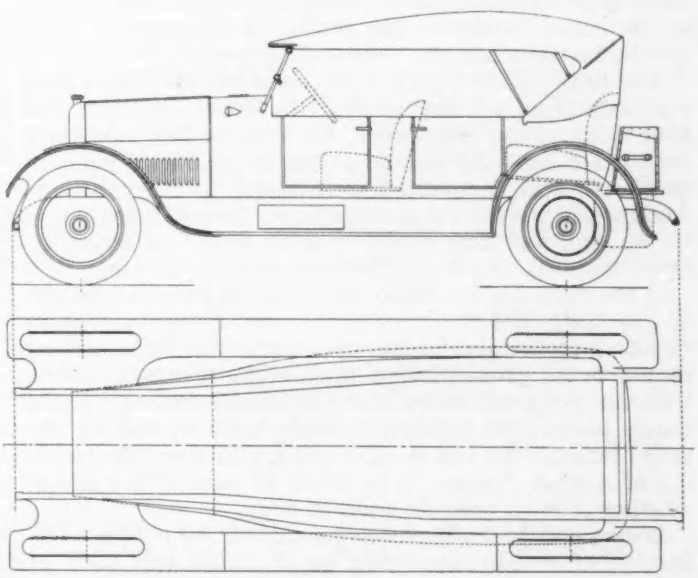
Annual Meeting Paper *Illustrated with* Drawings

THERE is a demand for economy in the running costs of automobiles. Gasoline costs more than ever before. The heavy car consumes more fuel and wears out tires more rapidly. Custom builders have not been urged by their customers to make cars of light weight, possibly because those who can afford custom bodies are not so vitally concerned with the cost of gasoline and tires as the purchasers of lower-priced bodies produced in quantities. Smaller engines can be built, but if the work they have to perform remains the same, these engines must use an equivalent amount of fuel. The work of the automobile engine is proportionate to the weight of the car and passengers, and we cannot decrease the weight of the men and women who ride in our cars. The chassis engineers think the body builders should be doing something toward a reduction of weight.

Nearly all the varied industries which, cooperating with each other, go to form the automobile industry, are comparatively new and of independent origin. One of the few exceptions, perhaps, is the automobile body business, which grew out of the manufacture of carriages, buggies and wagons. Chassis engineers criticize the body engineering fraternity at the present time because they feel they have reached very nearly the limit in lightweight chassis construction, whereas they think the body engineers have made practically no advance in the last 10 years. As a group of body men, we may admit that this is a fairly correct statement of the case. Perhaps one of the reasons why so little has been done on the problem of reduction in body weight during the last 10 years is that so many problems of this kind had been solved in the days of the horse-drawn vehicle.

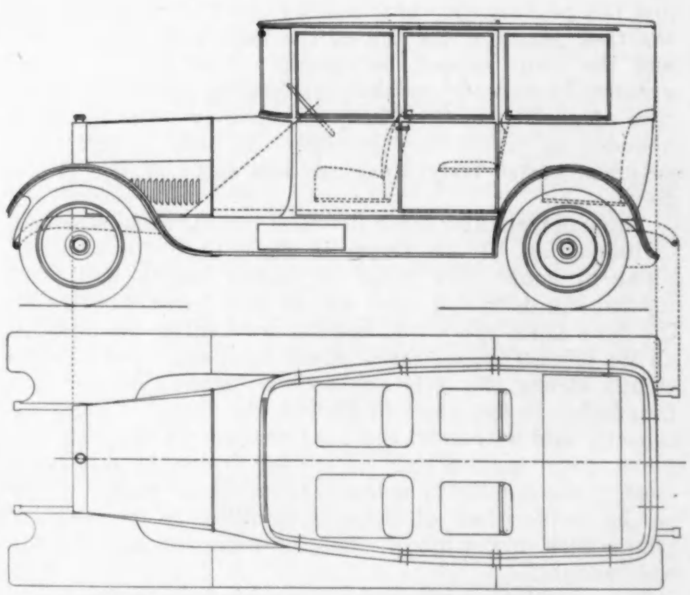
The phaetons, curricles, cabriolets, landaus, broughams and coaches of two decades ago were at the highest development they ever reached in style and construction. The quality of timber and all other material entering into carriage body building, as well as the character of workmanship, was of the very best that could be produced with the materials then available. This has been proved by examining carriage bodies built 50 and 100 years ago, which are still in good condition. Such bodies were built to stand the punishment of bad roads, cobblestones and deep ruts common years ago on country roads.

Buggies and two-passenger phaetons derived their lightness, combined with a remarkable carrying capacity, from the quality of timber and comparatively perfect workmanship entering into them. The landaus were the most troublesome bodies, considered in relation to light weight and carrying capacity, on account of the standing pillars being cut at the fence rails. But this very difficulty gave the body builders exact knowledge as to the dimensions of timber and the sizes of rocker plates required to sustain the weight of the body and the passengers, without any settling of the body on top of the fence rail, between the standing pillars.



Elevation and Plan Drawings of a Four-Passenger Touring Car Body Having an Extreme Overall Width of 54 In.

It is decidedly necessary that an automobile body should have a solid foundation. Past experience taught body builders a good lesson when the leather-top landaus were in fashion. These bodies had the doors cut at the fence rail, and the rocker plates were sufficiently strong to prevent the doors from closing up at the fence rails, in other words, at the top of the doors. These rocker



Elevation and Plan Drawings of a Seven-Passenger Sedan Body Having a Maximum Width of 56 In.

[1]Technical editor, *Vehicle Monthly*, Philadelphia.

plates were made $\frac{1}{2} \times 4\frac{1}{2}$ and $\frac{5}{8} \times 4\frac{1}{2}$ in. when the supports were 101 in. apart, which would correspond to what we call the wheelbase at present.

Application of Carriage Experience

This experience in the construction of open and closed carriage bodies was applied to automobile bodies, which is, in fact, the same as carriage work, and similar rules must be applied to their construction. Automobile bodies are constructed without rocker plates, and the frame has been substituted for them. Consequently, for the foundation of the body we have to depend on the body sills and the frame. Besides this, we must make a distinction between open and closed bodies, in other words, between touring cars and sedans.

The body builder's rule, then, must be not only to keep the body from settling so that the doors can open and shut without any hindrance, but also to keep the body from twisting. As the body builder is in no position to remedy such a condition by himself, he must work in conjunction with the chassis engineer from the beginning to the end, and each should consult the other as to the constructional details of the body and the frame.

If the frame is too weak, it will settle from the weight of the body and the passengers, and from the shocks resulting from uneven roadways. Consequently the frame should be in proportion to the weight it has to carry, with an extra allowance for the shocks caused by the rough roads. No automobile body, even though of the very best material and workmanship, will stand the twisting of a weak frame. It is bound to part at the joints, whether it is an open or a closed body.

Bodies can be built somewhat lighter to obtain a reduction of weight depending on the kind and style of bodies, but the body engineer can reduce the weight only under certain conditions, when these conditions are in his favor. First and most important is the carrying capacity of the frame. All others are only minor conditions.

A hindrance to lighter weight is the use of the same size of frame for a two-passenger runabout as for a six-passenger sedan. The frame is too heavy in the first case; when fitting a six-passenger sedan body on the same frame it may be too light. In other words, frames are frequently out of proportion to the weight of the body and the passengers. If a touring car frame is too weak the door joints at the top of the body will clinch tight, and the doors cannot be opened. This is one of the greatest inconveniences that can happen, especially in the case of accidents. The body engineer in such a case is helpless, no matter how strongly the body is built; the sills and entire body structure will settle if the frame does.

These defects also occur in closed bodies, such as sedans or limousines. If the frame is weak, the front standing pillar or coupé lock pillar on closed bodies will bend toward the door and close up the door joint, preventing the door from operating, besides weakening the body in all its joints. In all cases where the frame is not sufficiently strong the body engineer is helpless because the foundation is too weak to sustain the intended carrying capacity and withstand the road shocks. If the body engineer must build a body on a weak frame, he can avoid most of the trouble by using heavier sills or rocker plates on the inside edges of the sills or filling up the angular frame with stiff timber. This of necessity adds to the body weight.

The practice of using the same kind of frame for a two-passenger and a seven-passenger car is not to be recommended, as, in the case of the two-passenger car, the frame would be too heavy, and for the seven-passenger car it might be too light, and settling between the wheelbase supports might be the result. Reduction in the weight of automobile bodies may be possible, but the stability of the body on the frame must be retained. If the metal frame sags it carries the body with it at every downward movement; consequently the frame should be proportioned to rigidly support the weight of the passengers, and the body built on that frame should be as light as is consistent with stability.

According to the above observations, it is seen that the weight of bodies can be reduced only if the metal frame is designed as the real support of the weight of the passengers and the body. The weight can also be reduced if the frame is built in proportion to the amount of weight to be carried, the number of passengers and the style of bodies being considered. In the construction of closed bodies, however, such as sedans, coaches and broughams, very little weight can be saved if stability and lasting quality are to be retained.

An obstacle to lighter weight construction has sometimes been encountered in the widths of frames. French chassis builders have been content with a frame width of 28 in. across the front and $35\frac{1}{2}$ in. across the rear. These frames are suitable for narrow bodies about 50 in. wide, outside measurement, the same as the horse-drawn broughams and coaches were made. This width of $35\frac{1}{2}$ in. was tolerated by body builders, but the narrower the frame the wider the sills had to be made, because the entire length of the sills should rest on the frame to create a solid foundation. Suppose we have a frame 36 in. wide outside, and the width of body is 38 in. outside, with a 3-in. turn-under on each side. The recess caused by the narrow width of the frame when 36 in. wide, will be 11 in. on each side, or 13 in. when the sills have to rest on the frame, making the sills entirely out of proportion, and adding considerably to the weight. On account of the excessive amount of recess, the construction is weakened. American chassis engineers have made an improvement by widening the frame to 40 in. outside, a change which has strengthened the body and reduced its weight. If this width at the rear could be further increased for wide bodies, it would be an advantage to the body designer.

Chassis engineers have also made considerable improvement in the carrying capacity of the frame. In some instances, from the body designers' point of view, they have even gone too far, adding to the weight where it was not needed. A rule should be found to determine the carrying capacity of each frame, but this is difficult on account of the elasticity of the springs, the variability in the load carried, and the occurrence of road shocks. The old-time coach builder found out all he wanted to know by loading the body to its full capacity and then violently jolting it up and down.

Limitations in Weight Reduction.

The body engineer, of necessity, must work under certain limitations in any effort he makes to reduce body weight. There are some members of the body framework which must have certain sizes if strong and comfortable seats are to be provided for the passengers. Ample width and height of body are most important. If the width is unduly restricted the passengers will be uncomfortable, and the body must certainly be high enough to afford ample headroom. Both width and height add to the weight. This also applies to what is known as "knee room," which affects the length of the body and adds

considerably to the weight. The door and standing pillars must have a certain thickness where the windows move up and down, and a certain thickness to frame the doors and hold the door hinges and locks in their places.

Attention must be paid to the window regulators, which allow the body designer no leeway, since the lift occupies a certain space which cannot be reduced and still provide for the raising and lowering of the glass. Window regulators have supplied us with a convenience that car owners would not wish to dispense with, but they have added weight to the body besides their own.

Concealed door hinges are most desirable and practical, are invisible when the doors are closed and hardly visible when the doors are open. But additional space must be occupied to let them into the pillar, and at the same time the strength of the standing and door pillars must be preserved to prevent them from collapsing. The sizes of such pillars depend on the kind of concealed door hinges used and the pillars cannot be reduced in weight if the required strength is made the same as that of the door and side quarter glass lifts. When plain, straight or curved door hinges are used, the standing pillars can be reduced somewhat, but the amount of weight that can be saved here is so slight that it only counts in connection with other reductions. The weight of door locks has been reduced considerably, but when quality demands that the doors open and shut properly and easily, such locks must have some weight which cannot be reduced very much.

The parts of the body which add most to the weight, are the framework or frame structure of the body and the outside covering. The frame structure has been reduced almost to its limit, considering adequate strength for each part of the body, each part depending on the others to make a strong, solid structure. The sills on a body should not be less than 1½ in. in thickness and the width must be such that both sills rest on the frame. The top rails, cross bars and curves must have a certain size, below which the weight cannot safely be reduced. The outside covering of the body in present practice is either solid wood panels, sheet aluminum, sheet steel, or plywood. Wood panels are only used in connection with aluminum and for custom work. Sheet steel is preferred when a great number of bodies are produced in one model. In the past, plywood has been used chiefly for the tops on closed bodies, but it can be used to advantage where panels of other materials have formerly been used, if it can be shown that weight is saved thereby. For ease of working the metal and its light weight, aluminum has the preference.

I am sufficiently optimistic to believe that ways will be found to build lighter cars and lighter bodies. I have stated some of the limitations under which the body engineer must work, and it is only within such limits that any reductions in body weight can be made.

FARM POWER MEETING AND DINNER

(*Concluded from page* 280)

It is desirable that there should be on every farm electric lighting, power washing and every other similar convenience. Agriculture must be sufficiently remunerative to keep the boys and the girls on the farm. Marketing is just as important a function as production. The farmer recognizes that there must be community organization of the social phases of his life. The farmer does not desire to eliminate the middleman. He will insist upon modern agricultural equipment and upon the establishment and maintenance of a shorter route between producer and consumer. He wants more for the product of his toil, believing that then all others as well will receive more.

W. H. Stackhouse, president of the National Implement and Vehicle Association, whose members produce 93 per cent of the farm implement output of this country, addressed the members on the immediate problems of the farm operating equipment industry. He said that the $5,000,000,000 loss, which has been alluded to frequently as having been experienced by the farmers as a result in the shrinkage of the market value of their products, is a bookkeeping and not an actual loss. The farmers' losses cannot be determined before all their products on hand shall have been sold. Today the farmer has a tremendous buying power. He has never been and never will be a profiteer or striker.

Mr. Stackhouse quoted the Federal Trade Commission report to the effect that during the period from 1913 to 1918 the average price of farm implements increased 72 per cent. In this time all other commodities supplied to the farmer increased in price 97 per cent, and the farm products themselves 118 per cent. Considering the years 1913 to 1920, the increases were as follows: farm implements, 78 per cent; farm products, 112 per cent; labor, 115 per cent; other commodities, 144 per cent. Mr. Stackhouse said that farm implement prices will be reduced when the replacement cost in manufacture goes down. He paid a splendid tribute to standardization for its value in intelligent selective elimination of unnecessary sizes and immaterial differences in elements involved in manufacture. He said that work of this nature had saved the American farmer $10,000,000 last year. The Federal Trade Commission has reported that 22,000 different types of farm implement were being produced.

Fred Glover was most amiable and effective as toastmaster at the dinner.

The 1921 Standards Committee

IN view of the several broadening fields of standardization work, and of experience had in procedure, the intention has been to organize the Standards Committee in such a way as to maintain from year to year Divisions whose jurisdictions will be of a nature permitting prompt reference of almost any subject that may come up to some one Division. The Divisions are constituted of two classes, one representative of the respective automotive industries, and the other of parts and materials producers, arranged in a general grouping.

Matters pertaining to but one of the automotive industries will be referred to the Division representing it. Subjects that relate to two or more automotive industries will be assigned to the appropriate parts or materials Division and considered by this Division in conjunction with the respective automotive Divisions. For the purpose of strengthening and facilitating the work of the whole Committee, two Vice-Chairmen of the Standards Committee and a Vice-Chairman for each Division have been appointed. This will make more certain the attendance of a regularly appointed presiding officer at all Division sessions, as well as of the Chairman or a Vice-Chairman of the whole committee.

The Aeronautic Division and its several Subdivisions are retained practically as they were in 1920. The Isolated Electric Lighting Plant Division is broadly representative industrially of the field of farm and other isolated plant lighting which has expanded considerably during the past 2 years. The Motorboat Division is a continuance of the previous Marine Division. The Motorcycle, the Stationary Engine, the Tractor and the Truck Divisions are substantially the same as before. The 1920 Electric Transportation Division was divided into Subdivisions representative of electric passenger-cars and trucks, industrial trucks and tractors and the storage batteries used in these vehicles. It has been decided to discontinue temporarily standardization work in connection with industrial trucks and tractors as such, owing to lack of cooperative effort of the manufacturers in this field. The activities of the Electric Vehicle Division will refer to road vehicles of the type indicated by its name. The Storage Battery Division will handle all storage battery matters coming before the Standards Committee. Largely as a result of the very successful body-engineering session of the Society held in January and the interest manifested by designers and manufacturers, the Passenger Body Division has been created to take up suggestions for standardization of some phases of body construction and installation. It is expected that this Division will provide adequate means through which manufacturers can maintain effective cooperation for the solution of many problems in connection with the production of automobile bodies. The Lighting, Ball and Roller Bearings, Electrical Equipment, Engine, Frames, Iron and Steel, Non-Ferrous Metals, Radiator, Springs, Transmission and Lubricants Divisions are virtually the same as they were in 1920. The Miscellaneous Division, which has been active for many years, has been divided into the Parts and Fittings Division and the Screw Threads Division. Subjects pertaining principally to screw-thread specifications are usually of such a specialized nature as to warrant consideration of them in a separate Division. The new Chain Division is a continuance in combination of the Roller Chain Division and the Silent Chain Division. Although there is considerable inherent difference between the two classes of chain, it is desired that joint consideration of them shall be had. When matters relating strictly to one or the other class come before the Division, a special Subdivision will handle them.

Regulations Governing Standardization

The work of the Standards Committee is increasing in volume and scope, and requires more and more definite systematizing of procedure in the formulation and recommendation of standards. The Regulations Governing the Standards Committee have been revised as necessary and considered advisable during the past few years. They have been extended somewhat recently to read as follows:

The Standards Committee of the Society of Automotive Engineers may be composed of members or non-members of the Society.

FUNCTIONS

The Standards Committee under the discretion of the Council shall have jurisdiction over the formulation of all standards and recommended practices which may come before the Society for final adoption.

It may also be charged with such special deliberations or investigations as the Council may deem advisable or necessary for the preparation of authoritative reports.

The results of these investigations may, in the discretion of the Council, be made the subject of special reports.

ORGANIZATION

The Standards Committee shall act under the direction of a Chairman and two Vice-Chairmen, who shall be ex-officio members of each Division, and shall be assisted by a Standards Manager.

The whole Committee shall be resolved by the Council into a number of Divisions, each charged with the consideration of a group of subjects. Each Division shall be presided over by a Chairman or in his absence by a Vice-Chairman.

Any Division may be resolved further into such Subdivisions as the Division Chairman may deem expedient.

APPOINTMENTS

Appointments to membership on the Standards Committee shall be made annually by the Council in conference with the Chairman of the Standards Committee.

Interim appointments may be made by the Council.

The Chairman and the two Vice-Chairmen of the Standards Committee and the Chairmen and Vice-Chairmen of its Divisions shall be designated annually by the President of the Society.

The President and the Secretary of the Society shall be ex-officio members of the Standards Committee and of its Divisions.

PERSONNEL

Subdivisions—The Chairmen of Subdivisions shall be appointed by the respective Division Chairmen and shall preferably be members of the same Division.

Subdivision members may be members or non-members of the Society.

Appointments on Subdivisions shall be subject to the approval of the Standards Committee Chairman.

Division personnel in so far as feasible shall be representative of at least two groups, producers and users.

Divisions—Conferees of Divisions shall include all appointees who are not members of the Society. A conferee shall upon qualifying as a member of the Society

become a member of the Division. Conferees shall have no vote, but may serve in an advisory capacity and participate in discussions at all meetings.

One or more representatives of any one company may be appointed to Divisions or Subdivisions.

PROCEDURE

The order of business at Division or Subdivision meetings shall be:

Attendance registration
Approval of minutes
Subjects in progress
Revision of existing standards
Proposal of new subjects
Place and date of next meeting

In Subdivision—Reports on proposed new standards or revision of existing standards may issue from a Subdivision as preliminary reports only, and shall be submitted to the respective Division for approval.

In Division—Subdivision reports may be amended or referred back to the Subdivision by the Division.

However initiated, a proposed new standard or revision of an existing standard must issue as a report from that particular Division within whose province such matters properly belong, under assignment by the Council of the Society.

No action affecting the substance of a report shall be taken by any division except at a meeting called for that purpose or, at the discretion of the Standards Committee Chairman, by letter ballot of the Division. Approval of a report by letter ballot shall be by majority of the voting members of the Division. Voting by proxy is not permissible.

Reports shall consist generally of complete but concise statements of the practices and constructions, as recommended, together with such illustrations as may be necessary. There should be appended also explanatory remarks of the recommendations made.

A majority of voting members of a Division shall constitute a quorum thereof.

In the case of more than one member of the Division being associated with a given company, only one vote shall be cast on behalf of such members in Division meetings.

Dissenting members have the right to present minority reports individually or jointly.

All Division actions in meetings of the Division not approved by the vote of all the members of the Division shall be submitted by letter ballot to all the voting members of the Division.

In Standards Committee—Reports of the Division shall be submitted to the Standards Committee for approval at regular or special sessions.

Upon approval by the Standards Committee in original or amended form, Division reports shall be transmitted, with a statement of the action thereon, to the Council for approval in original or amended form for submission to the Society.

Fifteen members of the Standards Committee shall constitute a quorum.

Only members of the Standards Committee shall vote at Standards Committee meetings. The majority of those voting shall be necessary to approve a report. Voting by proxy is not permissible.

In Society Meeting—Division reports, when approved by the Council, shall be submitted to the Society for discussion at a duly called regular or special meeting.

Division reports may be amended or referred back with instructions.

A majority of the votes cast at a Society meeting by Society Members is necessary to approve reports for submission by letter ballot to the Members of the Society.

The Letter Ballot—Before adoption Division reports approved at a Society meeting shall be submitted by letter ballot to the voting members of the Society.

The letter ballot shall provide for the recording of affirmative and negative votes and waivers.

The letter ballot shall be returnable to the Secretary of the Society within 60 days following the Society meeting.

The letter ballots shall be opened and recorded 60 days following each Society meeting by three tellers appointed by the President of the Society.

The adoption of a report shall be determined by the majority of the letter ballots cast. Voting by proxy is not permissible.

MEETINGS

Committee Meetings—Meetings of the Standards Committee shall be held on the first day of or on the day preceding each Annual and each Semi-Annual Meeting of the Society. Special meetings may be held by direction of the Council.

Division Meetings—A meeting of a Division may, with the approval of the Standards Manager and the Secretary of the Society, be called on 10 days' notice, at the suggestion of the respective Division Chairman, or may be called on 10 days' notice by direction of the Secretary of the Society.

COMMITTEE RECORDS

Attendance—The Standards Manager or other representative of the Standards Department of the Society shall record the minutes, including the names of those in attendance, of Division or Subdivision meetings. In the absence of such representative, a suitable record of the proceedings of a meeting of a Division or Subdivision or of members thereof, shall be made by or by direction of the Chairman or Chairman pro tem of the meeting.

Members or conferees on Divisions or Subdivisions who are absent from two consecutive meetings shall be automatically discontinued from membership thereon except for adequate reasons, submitted in writing to the office of the Standards Committee or to the Division or Subdivision Chairmen.

Depository for Records—The Chairman of any Division or Subdivision or member thereof shall, after completion of work on any subject referred to the Division, transmit to the office of the Standards Committee any papers or correspondence relating thereto he may have in his possession.

MISCELLANEOUS

Publicity—A Division or Subdivision or a member thereof shall not have the right to issue matter for publication through other than the regular Society channels, unless so authorized for reasons of weight by the Council.

Stationery—Official correspondence, especially requests for information as to practice, should be conducted on official stationery, which will be furnished by the Secretary of the Society as necessary to Chairmen and members of Divisions or Subdivisions for use in conduct of special work.

Expenditures—No obligation for expenditures other than postage will be assumed by the Society unless such expenditure shall have been incurred in pursuance of previous authorization by the Council, and then only within specific fixed amounts.

WORK IN PROGRESS

There are approximately 200 subjects before the Standards Committee, including new assignments and proposed revisions of existing S.A.E. Standards and Recommended Practices. The work of revision is fundamentally important. The standards of the Society must keep pace with the progress in the industrial arts and sciences. The automotive and allied industries are enter-

ing upon a new era which will bring forth an improved and more healthy state of production, and the existing standards and those now being developed are and will be essential in securing adequate conservation of labor and material, reduction of costs, and improvement in quality of product.

THE PERSONNEL

The Standards Committee of the Society for the year 1921 is listed below in substantially complete form.

STANDARDS COMMITTEE

B. B. Bachman, *Chairman*
W. A. Chryst, *Vice-Chairman*
W. R. Strickland, *Vice-Chairman*

AERONAUTIC DIVISION

H. M. Crane, *Chairman*
Glenn L. Martin, *Vice-Chairman*

C. DeF. Chandler — L. B. Lent
V. E. Clark — G. C. Loening
W. L. Gilmore — G. J. Mead
L. M. Griffith — W. H. Phipps
G. E. A. Hallett — H. C. Richardson
J. L. Harkness — W. T. Thomas
J. C. Hunsaker — R. H. Upson
F. M. Kraus — C. M. Vought
P. W. Wittemann

Controls Subdivision

V. E. Clark, *Chairman*

L. B. Lent — G. C. Loening

Dope, Cement, Varnish and Glue Subdivision

W. T. Thomas, *Chairman*

J. C. Hunsaker — C. E. Waters
J. J. Moosmann — P. W. Wittemann

Materials Testing Subdivision

G. L. Martin, *Chairman*

J. C. Hunsaker — H. C. Richardson
J. B. Johnson — C. E. Waters
J. S. Macgregor — P. W. Wittemann

Performance and Testing Subdivision

G. L. Martin, *Chairman*

V. E. Clark — L. B. Lent
H. M. Crane — G. C. Loening
J. C. Hunsaker — H. C. Richardson
Alex Klemin — W. T. Thomas
K. M. Lane — C. M. Vought

Powerplant Subdivision

G. E. A. Hallett, *Chairman*

F. W. Caldwell — F. M. Kraus
Frederick Charavay — L. B. Lent
L. M. Griffith — G. J. Mead
E. J. Hall — C. M. Vought
L. M. Woolson

Tires and Wheels Subdivision

C. M. Vought, *Chairman*

J. V. Costello — J. C. Hunsaker
J. L. Harkness — L. B. Lent

Wire and Fittings Subdivision

G. L. Martin, *Chairman*

J. V. Costello — G. C. Loening
J. C. Hunsaker — H. C. Richardson

BALL AND ROLLER BEARINGS DIVISION

W. R. Strickland, *Chairman*
F. W. Gurney, *Vice-Chairman*

W. L. Batt — G. L. Miller
G. R. Bott — E. Nides
E. R. Carter — H. J. Porter
D. F. Chambers — R. G. Schaffner
F. G. Hughes — A. T. Sturt
R. E. Wells

CHAIN DIVISION

William F. Cole, *Chairman*
A. Ludlow Clayden, *Vice-Chairman*

W. J. Belcher — J. A. Kraus
A. E. Brion — F. L. Morse
H. F. Funke — H. S. Pierce
J. C. Howe — L. M. Wainwright
V. C. Young

ELECTRIC VEHICLE DIVISION

E. L. Clark, *Chairman*
Karl Probst, *Vice-Chairman*

G. M. Bacon — F. E. Queeney
J. G. Carroll — Charles A. Ward

ELECTRICAL EQUIPMENT DIVISION

A. D. T. Libby, *Chairman*
F. W. Andrew, *Vice-Chairman*

Azel Ames — T. L. Lee
W. A. Chryst — B. M. Leece
W. A. Frederick — C. Marcus
C. F. Gilchrist — R. G. Thompson
W. S. Haggott — A. H. Timmerman

ENGINE DIVISION

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J. B. Fisher, *Vice-Chairman*

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W. A. Frederick — A. J. Scaife
A. F. Milbrath — E. O. Spillman

FRAMES DIVISION

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F. R. Pleasonton, *Vice-Chairman*

J. M. Cook — O. B. Harman
L. J. Frelick — E. L. Larson

IRON AND STEEL DIVISION

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W. C. Peterson, *Vice-Chairman*

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C. N. Dawe — C. T. Moody
P. H. DeLong — J. H. Nelson
E. L. French — G. L. Norris
W. F. Graham — C. F. W. Rys
H. L. Greene — H. J. Stagg
Fletcher Harper — Samuel Tour

ISOLATED ELECTRIC LIGHTING PLANT DIVISION

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G. E. Tubbs, *Vice-Chairman*

T. P. Chase — E. B. Newill
A. S. Denes — C. E. Reddig
G. M. Gardner — E. L. Russell
L. W. Heath — Samuel Wilbur

LIGHTING DIVISION

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W. A. McKay, *Vice-Chairman*

Paul Bauder — C. A. Michel
T. C. Carruthers — Henry Platz
F. M. Holden — E. S. Preston
William E. Metzger — C. H. Sharp
J. C. Stearns

LUBRICANTS DIVISION

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W. E. Jominy, *Vice-Chairman*

A. P. Eves — W. H. Herschel
G. B. Upton

MOTORBOAT DIVISION

Joseph Van Blerck, *Chairman*
H. H. Brautigam, *Vice-Chairman*

Irwin Chase — William J. Deed
G. F. Crouch — H. E. Fromme
G. C. Davison — W. C. Morehead

MOTORCYCLE DIVISION

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C. B. Franklin, *Vice-Chairman*

A. J. Hall W. G. Henderson
F. W. Schwinn

NON-FERROUS METALS DIVISION

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Dr. E. Blough, *Vice-Chairman*

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G. K. Elliott H. P. Parrock
E. S. Fretz W. C. Peterson
Zay Jeffries W. B. Price
H. C. Mougey E. S. Wheeler
W. A. Woodward

PARTS AND FITTINGS DIVISION

Clarence Carson, *Chairman*
F. G. Whittington, *Vice-Chairman*

L. G. Bayrer C. W. Spicer
H. Jandus W. R. Strickland
W. C. Keys H. T. Thomas

PASSENGER BODY DIVISION

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E. Glenn Simpson, *Vice-Chairman*

William E. Biddle George Grimm
J. S. Burdick George W. Kerr
F. C. Chapman George J. Mercer
G. E. Goddard A. J. Neerken
H. C. Nelson

RADIATOR DIVISION

J. D. Harris, *Chairman*
C. S. Sage, *Vice-Chairman*

D. L. Britten C. T. Perkins
H. C. Harrison G. H. Pettit
H. B. Knap K. F. Walker
Charles Oppe E. E. Wemp

SCREW THREADS DIVISION

E. H. Ehrman, *Chairman*
O. B. Zimmerman, *Vice-Chairman*

Earle Buckingham Luther Burlingame
E. Burdsall W. R. Mitchell
A. J. Scaife

SPRINGS DIVISION

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S. P. Hesse, *Vice-Chairman*

H. R. McMahon Gustof Peterson
W. M. Newkirk F. A. Whitten

STATIONARY ENGINE DIVISION

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L. F. Burger, *Vice-Chairman*

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H. C. Gibson V. E. McMullen
T. A. Hicks C. J. Nelson
L. M. Ward

STORAGE BATTERY DIVISION

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G. M. Bacon, *Vice-Chairman*

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E. L. Clark C. T. Klug
R. I. Ellis I. M. Noble

TRACTOR DIVISION

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H. C. Buffington, *Vice-Chairman*

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A. H. Gilbert C. B. Rose
R. O. Hendrickson A. W. Scarratt
C. Edward Johnson O. W. Sjogren
J. Mainland L. W. Witry
G. A. Young

TRANSMISSION DIVISION

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A. C. Bryan, *Vice-Chairman*

J. B. Foote W. C. Lipe
L. C. Fuller C. E. Swenson
A. A. Gloetzner S. O. White

TRUCK DIVISION

A. K. Brumbaugh, *Chairman*
F. A. Whitten, *Vice-Chairman*

D. L. Arnold C. O. Guernsey
W. M. Britton M. C. Horine
J. R. Coleman H. B. Knap
F. W. Davis A. J. Scaife

OIL-BURNING VESSELS

FIGURES compiled by the American Petroleum Institute from the 1920 and 1919 reports of the bureau of navigation, Department of Commerce, show a total of 1367 vessels in the American merchant marine of 500 gross tons and over equipped for burning oil fuel in 1920, as against 762 vessels in 1919. The 1920 figures are corrected to Oct. 1, 1920, and the 1919 figures are for the fiscal year ended June 30, 1919. The figures follow:

	Number of Vessels	Gross Tons
1920	1,367	6,462,411
1919	762	3,510,465
Increase, 1920	605	2,951,946

The increase of 605 vessels, representing 2,951,946 gross tons, is a significant index to the growth of marine requirements for fuel oil for the period. Included in the total figures given are 230 tank vessels, aggregating 1,334,127 gross tons, in 1920, and 162 tankers, aggregating 905,237 gross tons, in 1919, equipped for burning fuel oil. Of the aggregate number of vessels equipped for burning fuel oil in 1920, 946, with a gross tonnage of 4,334,428 tons, were Shipping Board vessels.

AIR MAIL SERVICE

THE United States was the first country in the world to establish a regular Air Mail Service, that between Washington and New York City, which was opened May 15, 1918. Since then the Service has been extended to San Francisco, St. Louis and Minneapolis and St. Paul. Thirty-five cargo-carrying mail planes are in the air each day, flying a total of 8000 miles.

Since the experimental line between Washington and New York City was started, England, France, Belgium, Germany, Italy, Switzerland, Czecho-Slovakia and the Scandinavian countries have established air mail routes, the most notable of which are those connecting London and Paris, Copenhagen, London and Amsterdam, Paris and Prague and Berlin, Hamburg and Munich.

The coast-to-coast air mail provides the means for greatly reducing the time of rail transportation, and the introduction of night flying which is imminent will enable letters to be transported from New York City to San Francisco in two days or less. During the calendar year 1920 the Air Mail Service carried about 103,000,000 letters.

PIGEONS IN NAVAL AVIATION

THE Navy Department has issued a statement giving statistics recently compiled concerning the part played by pigeons in Naval Aviation during the war. It is stated that during the last 10 months of the war United States Naval pigeons delivered 219 messages from seaplanes forced to land at sea and which were without any other means of communication.

Applicants *for* Membership

The applications for membership received between Jan. 28 and Feb. 21, 1921, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ARDERN, JAMES S., service manager, Northway Motor Sales Co., *Boston.*

ARMINGTON, A. P., superintendent and engineer, Euclid Crane & Hoist Co., *Euclid, Ohio.*

BERGLING, NILS K. A., draftsman, Holt Mfg. Co., *Stockton, Cal.*

COBB, E. E., service and sales manager, U. S. Malleable Iron Co., *Toledo.*

COLE, W. F., chief inspector automobile body department, Osgood Bradley Car Co., *Worcester, Mass.*

COMFIELD, EINAR A., chief draftsman, Available Truck Co., *Chicago.*

CUMMINGS, STANLEY R., instructor, Massachusetts Institute of Technology, *Cambridge, Mass.*

DELANY, HOWARD S., partner, Delany & Co., *Tacony, Philadelphia.*

DELAVAL-CROW, THOMAS CLIVE, chief engineer, New Departure Mfg. Co., *Bristol, Conn.*

EATON, WILLIAM S., director body department, Dupont Motors, Inc., *Moore, Pa.*

FORDYCE, THOMAS N., district representative, Willard Storage Battery Co., *Cleveland.*

GIBSON, RICHARD, JR., technical superintendent, Lancaster Tire & Rubber Co., *Lancaster, Ohio.*

GOTTRON, ROBERT E., chief engineer, Weger Aeronautical Motor Co., *Cleveland.*

GROSS, EDWARD L., vice-president, Perolin Co. of America, *Chicago.*

HARDY, LEO J., draftsman, Osgood Bradley Car Co., *Worcester, Mass.*

HARVEY, CHARLES A., designing draftsman, Erie Motor Truck Mfg. Co., *Erie, Pa.*

HENRY, GUY P., chief engineer, Studebaker Corporation, *Detroit.*

HOOD, CLIFFORD F., superintendent, electrical cable works, American Steel & Wire Co., *Worcester, Mass.*

HUBBARD, HENRY M., designer, tank, tractor and trailer division, district engineering office, Ordnance Department, *Cleveland.*

HULT, DEWEY E., mechanical draftsman, Toro Mfg. Co., *Minneapolis.*

KAZEY, A. R., charge of engineering department, Ross Gear & Tool Co., *Lafayette, Ind.*

KNAPP, ARCHER L., assistant body engineer, Packard Motor Car Co., *Detroit.*

LA GUIRE, RAYMOND F., laboratory assistant, Joseph Tracy, *New York City.*

LANE, KENNETH M., aeronautical engineer, Dayton-Wright Co., *Dayton, Ohio.*

LARKIN, WALTER P., superintendent jobbing division, Bock Bearing Co., *Toledo, Ohio.*

LUTMAN, HARRY L., machine designer, Western Electric Co., Inc., *Chicago.*

MCCONNELL, WILLIAM G., assistant sales manager, Oklahoma Auto Mfg. Co., *Muskogee, Okla.*

MACVICHIE, DONALD, general manager, Motor Car Service Bureau, *Danville, Ky.*

MEYER, GEORGE L. N., 796 Marietta Avenue, *Milwaukee, Wis.*

NAKADA, KYOICHI, assistant chief designer, Tokyo Gas & Electric Industrial Co., Ltd., *Tokyo, Japan.*

OSTERMAN, HANS, president, Aktiebolaget Scavia-Vabis, *Stockholm, Sweden.*

OUTCALT, WILLIAM J., head of standard parts department, General Motors Corporation, *Detroit.*

PARRISH, RIAL T., chief engineer, Two-Way Plow Tractor Co., *Dayton, Ohio.*

PHILLIPS, GEORGE C., body engineer, Auto Body Co., *Lansing, Mich.*

PROPER, LESLIE E., body designer, Durant Motors, Inc., *Long Island City, N. Y.*

REEVE, EDWARD, superintendent, Wolseley Motors, Ltd., Adderley Park, *Birmingham, England.*

SHAFER, WILLIAM H., secretary and superintendent, Ahrens-Fox Fire Engine Co., *Cincinnati.*

SHIDLE, NORMAN G., editorial staff, *Automotive Industries, New York City.*

SOUTHARD, SEWALL CLARKE, student, Tri-State College of Engineering, *Angola, Ind.*

WEINERT, RICHARD H., efficiency engineer, Studebaker Corporation, *Detroit.*

WESTMAN, E. E., secretary and treasurer, Kant Kut Tube Products Co., *Indianapolis.*

WHEAT, E. F., superintendent, Y. M. C. A. Automobile School, *St. Louis.*

WHITE, EARL A., editor, *Farm Implement News, Chicago.*

WILLIAMS, IVOR H., assistant engineer, Weger Aeronautical Motor Co., *Cleveland.*

WILLIAMS, J. J., general production superintendent, Federal Rubber Co., *Cudahy, Wis.*

WITTE, OTTO A., secretary and chief engineer, American Bureau of Engineering, Inc., *Chicago.*

WITTER, HARRY L., lubricating engineer, Standard Oil Co., *Detroit.*

WOOD, ELLERY CHANNING, engineer, Petroleum Heat & Power Co., *Boston.*

WOOD, E. ELLSWORTH, engineer, Miniature Incandescent Lamp Corporation, *Newark, N. J.*

WRIGHT, WILLIAM E., experimental engineer, Waukesha Motor Co., *Waukesha, Wis.*

YOUNGS, ARTHUR, manager, Youngs & Co., *Newburgh, N. Y.*

Applicants *Qualified*

The following applicants have qualified for admission to the Society between Jan. 10 and Feb. 10, 1921. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member; (E S) Enrolled Student.

ACKERMANS, JOHN W. J. (M) experimental and sample body engineer, E. J. Thompson Co., *Pittsburgh,* (mail) 7309 Hamilton Avenue, Homewood.

BALL, GEORGE E. (S M) Headquarters 6th Corps, *Fort Sheridan, Ill.*

JONES, RICHARD L. (A) president, Auto Leather Mfg. Co., *Arlington, N. J.*

KROYER, J. M. (M) president, Kroyer Motors Co., P. O. Box 477, *Stockton, Cal.*

LAMBERT, G. F. (M) chief engineer, Kroyer Motors Co., *Stockton, Cal.*

MACCORMACK, J. G. (S M) assistant to the director of training, transportation corps, Motor Truck Division, *Washington,* (mail) 1825 Columbia Road.

NASH, CARLETON BIRTLEY (J) assistant engineer, Maccar Truck Co., *Scranton, Pa.,* (mail) 426 Colfax Avenue.

NEILL, GEORGE G. (A) Air Service, Washington.

NEWMANN, ARTHUR B. (M) tractor designer, Holt Mfg. Co., *Peoria, Ill.* (mail) 309 West Armstrong Avenue.

RAPP, ARTHUR H. (J) draftsman, Watson Products Corporation, *Canastota, N. Y.,* (mail) 133 West Chapel Street.

ROSE, HARRY (M) business manager, W. D. Block Motor Co., 200 State Street, *Grand Rapids, Mich.*

SHEELINE, PAUL D. (J) commercial engineer, A. D. Little, Inc., *Cambridge, Mass.,* (mail) 55 Magazine Street.

SIBLEY, B. E. (A) automotive engineer, lubrication department, Continental Oil Co., Denver, Col.

THOMPSON, JOHN F. (M) manager of technical department, International Nickel Co., 43 Exchange Place, *New York City.*

VANNEMAN, JOHN A. (M) engineer, Eisemann Magneto Corporation, *Brooklyn, N. Y.,* (mail) 1488 Union Street.

WATKIN, L. M. (A) Eastern sales manager, Standard Steel & Bearings, Inc., *Philadelphia,* (mail) 1017 Marlyn Road.

YOUNG, EARLE L. (A) factory manager, Laminated Shim Co., Inc., New York City, (mail) 1112 Park Avenue, *Hoboken, N. J.*